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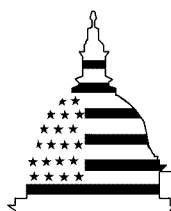
Report to the Ranking Minority Member,  
Committee on Governmental Affairs,  
U.S. Senate

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April 2002

# EXPORT CONTROLS

## Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review



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## Report Documentation Page

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<b>Abstract</b> The United States controls the export of certain technology, including some of the equipment and materials used to make semiconductors, to sensitive destinations such as China for national security or foreign policy reasons. Semiconductors, commonly referred to as computer chips, are key components in computers, communications equipment, and weapons systems. U.S. policy on the export of such dual-use items goods and technologies that have both civilian and military uses is a subject of continuing debate. This policy strives to balance the need to protect U.S. national security and foreign policy interests with the objective to promote U.S. trade and competitiveness. As part of its efforts to control exports of sensitive dual-use technology, the United States is a member of the Wassenaar Arrangement a forum of 33 countries established in 1996 to reach multilateral agreements about which dual-use goods merit special scrutiny and reporting. <sup>1</sup>				
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## EXPORT CONTROLS

### Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review

Highlights of GAO-02-620, a report to the Ranking Minority Member, Committee on Governmental Affairs, U.S. Senate

#### Why GAO Did This Study

The United States controls the export of certain technology, including some of the equipment and materials used to make semiconductors, or computer "chips," to sensitive destinations such as China for national security or foreign policy reasons.

In light of China's efforts to acquire modern semiconductor manufacturing technology, GAO was asked to assess (1) advances in China's manufacturing capability, and (2) U.S. export control policy for this technology and its analytical basis.

#### What GAO Recommends

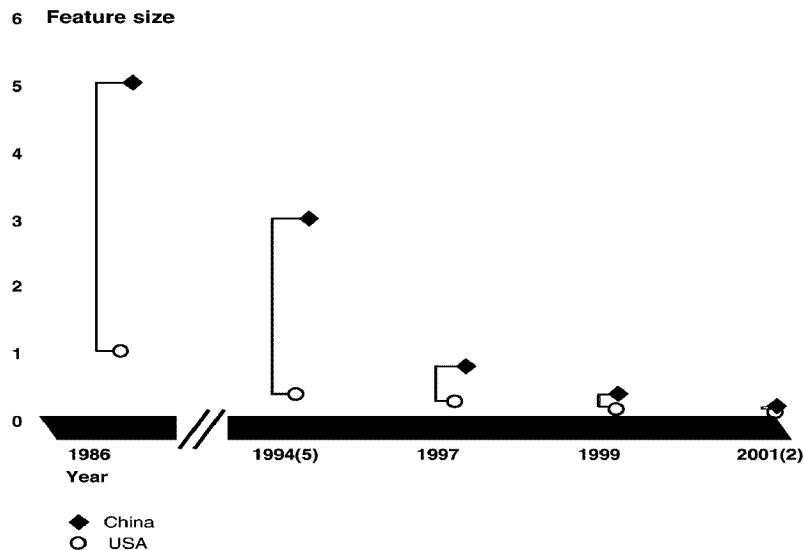
GAO recommends that the secretaries of commerce, defense and state reassess, document, and update as necessary U.S. policy and practices on exporting semiconductor manufacturing equipment and materials to China.

The agencies disagreed with this recommendation stating that their current policies and practices are sufficient for making export licensing decisions to China.

We disagree. U.S. export regulations governing China contain inherent inconsistencies and are based on outdated government assessments of the availability of technology from non-U.S. sources. Accordingly, our recommendations remain unchanged.

#### What GAO Found

Since 1986, the gap between U.S. and Chinese semiconductor manufacturing technology has rapidly narrowed (See chart). Today, China's advanced manufacturing facilities can make chips that are less than one generation behind the current, commercial state of the art.



The gap between U.S. and Chinese semiconductor manufacturing technology, as measured in the feature size of the semiconductors produced, rapidly diminished in recent years. A semiconductor's feature size is measured in microns and is used to define the current level of technology.

U.S. policies and practices to control the export of semiconductor technology to China are unclear and inconsistent leading to uncertainty among U.S. industry officials about the rationale for U.S. government licensing decisions.

- While export regulations restrict certain sales that would make a direct and significant contribution to China's military capabilities, the United States generally approves most exports of semiconductor manufacturing equipment and materials to China.
- Although the stated practice of U.S. export agencies has been to keep China two generations behind state of the art semiconductor production capabilities, U.S. regulations do not describe the level of allowable technology that can be exported to China relative to the commercial state of the art.
- The Departments of Commerce and Defense have not conducted recent national security and economic assessments to form a sound analytical basis for exporting semiconductor technology to China.

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United States General Accounting Office  
Washington, D.C. 20548

April 19, 2002

The Honorable Fred Thompson  
Ranking Minority Member  
Committee on Governmental Affairs  
United States Senate

Dear Senator Thompson:

The United States controls the export of certain technology, including some of the equipment and materials used to make semiconductors, to sensitive destinations such as China for national security or foreign policy reasons. Semiconductors, commonly referred to as computer “chips,” are key components in computers, communications equipment, and weapons systems. U.S. policy on the export of such “dual-use” items—goods and technologies that have both civilian and military uses—is a subject of continuing debate. This policy strives to balance the need to protect U.S. national security and foreign policy interests with the objective to promote U.S. trade and competitiveness. As part of its efforts to control exports of sensitive dual-use technology, the United States is a member of the Wassenaar Arrangement—a forum of 33 countries established in 1996 to reach multilateral agreements about which dual-use goods merit special scrutiny and reporting.<sup>1</sup>

Because of your concerns about whether the United States’ national security and foreign policy interests are being adequately protected, particularly in light of the pace at which China has been acquiring modern semiconductor manufacturing technology, you asked that we

1. describe advances in China’s semiconductor manufacturing capability and the impact of these advances on its industrial base;
2. analyze how the Wassenaar Arrangement has affected the transfer of semiconductor manufacturing technology to China; and

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<sup>1</sup>The 33 participating states of the Wassenaar Arrangement are: Argentina, Australia, Austria, Belgium, Bulgaria, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Republic of Korea, Romania, Russian Federation, Slovak Republic, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, and the United States.

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3. describe U.S. policy and practice regarding the export of this manufacturing technology to China and assess its analytical basis.

To address these issues, we spoke to more than 170 representatives from academia, industry, and U.S. and foreign governments. In addition, we collected and analyzed information from the U.S. Departments of Commerce, Defense, and State; and from various industry and trade associations. Our work focused on China and its newest semiconductor manufacturing facilities. We visited manufacturing facilities, government agencies, and research organizations in China. Further, we analyzed Commerce Department licensing review and approval data and analyzed export reporting and proposal acceptance and rejection data provided by the Wassenaar Arrangement Secretariat in Vienna, Austria.<sup>2</sup>

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## Results in Brief

Since 1986, China's efforts to improve its semiconductor manufacturing capability have narrowed the gap between U.S. and Chinese semiconductor manufacturing technology from between 7 to 10 years to 2 years or less. According to our analysis of information obtained from semiconductor manufacturing facilities in China and industry experts, China's most advanced commercial manufacturing facilities can produce chips that are only one generation behind current, commercial state-of-the-art technology. China has made improving its semiconductor manufacturing capability a priority for national and economic security reasons and plans to build as many as 20 multibillion-dollar manufacturing facilities over the next 5 to 10 years with substantial levels of foreign investment. The growing sophistication of China's semiconductor manufacturing facilities, which has improved its ability to develop more capable weapons systems and advanced consumer electronics, has been fueled by China's success in acquiring manufacturing technology from abroad.

The multilateral Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies has not affected China's ability to obtain semiconductor manufacturing equipment because the United States is the only member of this voluntary arrangement that

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<sup>2</sup>We issued a separate For Official Use Only version of this report in February 2002. U. S. General Accounting Office, *Export Controls: Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review*, GAO-02-151 (Washington, D.C.: Feb. 19, 2002). Agency comments in this report containing information designated For Official Use Only have been redacted.



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considers China's acquisition of semiconductor manufacturing equipment a cause for concern. The arrangement deems only one type of semiconductor manufacturing equipment to be sufficiently sensitive to warrant greater information sharing among arrangement members—no export information is shared for 97 percent of all electronics-related items covered by the arrangement. Transparency, through exchanging information and sharing views, is the sole means by which the arrangement tries to achieve its goals. Over the past several years, fewer items have been subject to the Wassenaar Arrangement, particularly electronics-related items.

U.S. policies and practices to control the export of semiconductor technology to China are unclear and inconsistent, leading to uncertainty among U.S. industry officials about the rationale for some licensing decisions. Under the Export Administration Regulations pertaining to China, the general licensing policy is to approve applications, except those items that would make a direct and significant contribution to specific areas of China's military. We found that the United States approves most licenses for exports of semiconductor manufacturing equipment and materials to China. Although U.S. practice has been aimed at keeping China at least two generations (about 3 to 4 years) behind global state-of-the-art semiconductor manufacturing capabilities, the regulations make no reference to the level of technology that can be exported to China relative to the current commercial state of the art. Further, U.S. agencies have not conducted the analyses, such as assessing foreign availability of this technology or the cumulative effects of such exports on U.S. national security interests, necessary to justify such a practice or serve as the basis for licensing decisions. Consequently, the executive branch does not have a sound, well-documented basis for making export-licensing decisions to China.

In this report, we are recommending that the secretary of commerce, in consultation with the secretaries of defense and state, reassess and document U.S. export policy on semiconductor manufacturing equipment and materials to China. Specifically, we are recommending that these agencies complete the analyses needed to serve as a sound basis for an updated policy; develop new export controls, if appropriate, or alternative means for protecting U.S. security interests; and communicate the results of these efforts to the U.S. Congress and industry.

In commenting on a draft of this report, the Departments of Commerce, Defense, and State said that our report was based on an invalid assumption that the goal of U.S. export control policy is to keep China's industry two

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generations behind U.S. industry. These agencies said that U.S. policy for why and how these items should be controlled can be found in the Export Administration Regulations and is based on a sound analytical framework.

We agree with the Departments of Commerce, Defense, and State that a description of the U.S. government's export control policy toward China is found in the Export Administration Regulations. We added some additional information to the report to better describe this policy and to make a clearer distinction between policy and practice as the current regulations make no reference to the level of semiconductor manufacturing technology that can be exported to China relative to the current commercial state of the art. We found that the executive branch practice was aimed at keeping China two generations behind the U.S. semiconductor manufacturing industry. On March 1, 2001, the under secretary for export administration (a policy-level official), described this practice and reconfirmed it in a follow-up January 2002 meeting with GAO after he left office.

Moreover, in commenting on our draft report, the Commerce Department described this practice, noting that "certain exports of semiconductor manufacturing equipment to China are limited to two generations behind state-of-the-art levels to address national security, or other concerns related to a particular transaction."

Regarding the Departments of Commerce, Defense, and State's comments that the current export licensing process is based on a sound, analytical framework, we found that a U.S. government foreign availability analysis of semiconductor manufacturing equipment has not been completed since 1987. Further, the U.S. government has not conducted studies of the cumulative effect of the export of advanced semiconductor manufacturing equipment and materials to China on U.S. national security.

The findings, conclusions, and recommendations of our report remain unchanged.

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## Background

Semiconductors or “computer chips” are critical components in everything from automobiles to weapon systems.<sup>3</sup> They contain millions of transistors and other components that are smaller than 1/100 the width of a human hair. The manufacture of integrated circuits involves a complex, 250-step process utilizing hundreds of millions of dollars in technologically advanced equipment and purified materials.

An integrated circuit’s component size—or feature size—is measured in microns; modern chips range from 0.35 micron to 0.13 micron.<sup>4</sup> Smaller feature size allows for more components to be integrated on a single chip, thus creating more powerful chips. The semiconductor industry also uses feature size to define the current level of integrated circuit technology: Each reduction in feature size, for example, from 0.35 micron to 0.25 micron, is considered a move to a new generation of technology.<sup>5</sup>

According to Semiconductor Equipment and Materials International, the \$76 billion global semiconductor equipment and materials industries (\$48 billion and \$28 billion, respectively) serve as the foundation for the \$204 billion semiconductor industry, which in turn supports many other industries including the \$1.1 trillion electronics industry.<sup>6</sup> The equipment and materials industries produce a variety of equipment, chemicals, gases, films, and other materials critical to manufacturing integrated circuits. U.S. companies created and dominated the semiconductor equipment and materials industries until the early 1980s, when Japan increased investment and Japanese companies gained a greater market share in several critical

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<sup>3</sup>Semiconductor materials, such as silicon, can be used as both a conductor and insulator of electricity. Almost all of today’s computer chips are constructed on wafers made of 99.9999 percent pure silicon, although other materials such as gallium arsenide may also be used for specific applications. The term “semiconductor” also refers to devices that are manufactured from semiconductor materials. Semiconductors include discrete devices, such as transistors, and integrated circuits comprising millions of transistors and other components. For the purposes of this report, the terms semiconductor, integrated circuit, and computer chip are used interchangeably.

<sup>4</sup>One micron is one-millionth of a meter or 1/100th the width of a human hair.

<sup>5</sup>Each new generation of technology represents a reduction of approximately 28 percent of the previous generation’s feature size. This term applies exclusively to silicon-based, very large-scale integrated circuit technology (that is, circuits with 100,000 to 1 million components).

<sup>6</sup>Semiconductor Equipment and Materials International is the trade association serving the global semiconductor equipment, materials, and flat panel display industries.

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equipment and materials technologies. During the 1990s, U.S. companies regained market share and currently share worldwide leadership with Japan, although Japan still dominates the key silicon manufacturing and lithography markets.<sup>7</sup>

The global semiconductor equipment and materials industries comprise more than 2,400 small to medium-sized companies located primarily in the United States, Japan, and Europe. Typically these companies manufacture equipment or materials required for just one or two of the numerous processes for making integrated circuits. In 2000, 10 companies accounted for approximately 63 percent (\$30.3 billion) of the equipment industry's \$48 billion revenue.<sup>8</sup>

One of the reasons semiconductor equipment and materials are controlled is their potential role in improving a nation's military capabilities. The Export Administration Act of 1979,<sup>9</sup> as amended, and the implementing Export Administration Regulations authorize the Commerce Department to require firms to obtain licenses for the export of sensitive items that may pose a national security or foreign policy concern.<sup>10</sup> The Departments of Commerce, Defense, and State and others review export license applications. The Commerce Control List provides detailed specifications for about 2,400 dual-use items that require export licenses to particular destinations for largely national security and foreign policy reasons. (See app. I for additional information on the Commerce Control List.) Semiconductors and related equipment and materials fall under the list's "Category 3" (electronics), with manufacturing equipment and materials placed in Category 3B (test, inspection, and production equipment) and

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<sup>7</sup>Lithography is a manufacturing process used to imprint circuits on semiconductor materials.

<sup>8</sup>The top 10 materials companies accounted for approximately 42 percent (\$11.7 billion) of the industry's \$28 billion revenue in 1999—the last year for which complete information was available.

<sup>9</sup>Since August 20, 1994, when the Export Administration Act of 1979 was terminated, several executive orders and one law have extended application of the act. Most recently, application of the act has been extended by Executive Order 13222, Aug. 17, 2001 (66 Fed. Reg. 44025).

<sup>10</sup>50 U.S.C. App. sections 2401 and following and 15 C.F.R. sections 730 and following.

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3C (materials), respectively.<sup>11</sup> Category 3 goods and technologies are controlled primarily as a tool of U.S. anti-terrorism policy, but also to meet nuclear nonproliferation policy objectives, control the spread of missile technology and crime, and address general national security concerns.<sup>12</sup> The primary control concern regarding China is national security. In many cases, items on the Commerce Control List will require a license only if they are going to a particular country. However, some products will require a license because (1) there is a risk of diversion to an unfriendly destination; (2) the nature of the product makes it sensitive; or (3) the end use or end user of the product triggers concerns.<sup>13</sup>

As part of its efforts to control exports of sensitive dual-use technology, the United States is a member of the Wassenaar Arrangement. The Wassenaar Arrangement, the successor regime to the Coordinating Committee for Multilateral Export Controls, came into existence in July 1996.<sup>14</sup> It is built on a broad international consensus that new threats to global security from the spread of weapons of mass destruction and their delivery systems make multilateral export controls on dual-use items necessary. The Wassenaar Arrangement was designed to complement and reinforce, without duplication, the other existing international export control regimes for weapons of mass destruction and their delivery systems.<sup>15</sup> The arrangement was explicitly charged in its founding documents to prevent “destabilizing accumulations” of dual-use goods and technologies that may be used to

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<sup>11</sup>Group B and C items are described in 15 C.F.R., Part 774, Supp. 1.

<sup>12</sup>See C.F.R. 15 Part 774.

<sup>13</sup>The U.S. government controls some items unilaterally to particular countries for specific purposes. For example, some items in Category 3B are controlled multilaterally through the Wassenaar Arrangement but are controlled more strictly to particular countries by the United States for antiterrorism purposes.

<sup>14</sup>The Coordinating Committee for Multilateral Export Controls was established early in the cold war and included all NATO countries except Iceland, plus Japan and Australia. Members agreed not to export specified, listed dual-use goods and technologies to Soviet bloc countries and China and to obtain unanimous preapproval for any nonprohibited exports.

<sup>15</sup>Each of the other existing regimes focuses on one general category of weapons of mass destruction. The Nuclear Suppliers Group aims to tightly control access to nuclear exports to reduce the possibility that such transfers could be diverted to nuclear explosive or unsafeguarded nuclear fuel cycle activities. The Australia Group seeks to control the spread of chemical and biological warfare agents. The Missile Technology Control Regime seeks to control the export of missiles or related equipment that can be used to produce a missile with a range of at least 300 kilometers capable of delivering any payload.

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contribute to the development or enhancement of military capabilities that would undermine regional security and stability.<sup>16</sup> Transparency, through exchanging information and sharing views, is the sole means by which the arrangement tries to achieve its goals. According to a senior State Department official on detail to the Wassenaar Secretariat and Wassenaar documents, members of the arrangement make a threefold political commitment to: control exports of selected advanced dual-use goods and technologies; refrain from exporting dual-use items that may, according to national judgment, contribute to weapons proliferation or regional or international instability; and inform other Wassenaar member governments of selected approvals and denials of export licenses for these items.

These commitments may or may not lead a member state to deny an export license. The “control” aspect of the arrangement resides entirely in the discretion of national governments that commit only to scrutinize selected dual-use goods and technologies. Members have no power to veto other members’ sales. Like its predecessor regime, the arrangement does not enjoy formal treaty status. The Wassenaar Arrangement is not directed against any state or group of states. Although there is an informal understanding that exports to Iran, Iraq, Libya, and North Korea bear special scrutiny, no countries are specifically named as targets of the arrangement. Even this informal understanding does not hold in all cases among all Wassenaar members. The Russian representative to Wassenaar, for example, noted that for export control purposes the Russian government considers Iran a “normal country.”

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<sup>16</sup>The arrangement also provides for the exchange of information among its members on exports of conventional munitions. We did not review this aspect of the arrangement because it is not relevant to semiconductor manufacturing technology.

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## Rapid Advances in Semiconductor Manufacturing Capability Have Improved China's Commercial and Defense Industrial Base

Since 1986, China's efforts to improve its semiconductor manufacturing capability have resulted in a narrowing of the gap between U.S. and Chinese semiconductor manufacturing technology. Today, China's most advanced semiconductor manufacturing facilities can produce integrated circuits that are only one generation or less behind the current state of the art. Acquiring semiconductor technology and know-how is a priority of the Chinese government.<sup>17</sup> The country's improvements in semiconductor manufacturing capability are the direct result of the involvement of European, Japanese, and U.S. integrated circuit manufacturers in China, typically through joint ventures or wholly foreign owned manufacturing facilities. Currently, China has eight major integrated circuit manufacturing facilities with substantial levels of foreign investment or ownership. The country's rapid advances in this sector have integrated China into the global semiconductor industry, improved China's commercial and defense industrial base, and created a potential new source of sophisticated integrated circuits for China's industry and military.

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## Technology Gap Between United States and China Is Narrowing Rapidly

Fifteen years ago, China was five generations of technology behind the United States' then-current commercial production capability, according to industry experts we interviewed. Today, China has narrowed this technology gap. Although the equipment in China's newest manufacturing facilities is designed to produce integrated circuits with 0.25-0.18 micron feature sizes, it can be fine-tuned to produce integrated circuits with 0.18-0.13 micron feature sizes or less in some cases, according to semiconductor manufacturing experts with whom we spoke.<sup>18</sup> Consequently, the most advanced semiconductor manufacturing facilities in China today can

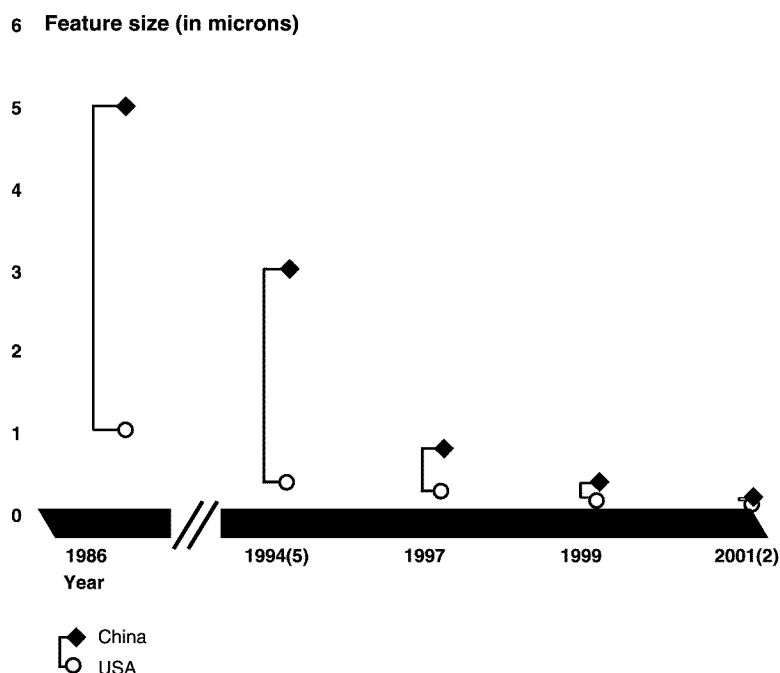
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<sup>17</sup>This goal was first stipulated in China's Eighth 5-year Economic Plan (1991-1995).

<sup>18</sup>Fine-tuning the equipment to produce integrated circuits with smaller features decreases the size of the integrated circuits and, therefore, increases the number that can be produced on a given wafer. However, this can only be carried so far before decreasing yields (due to small feature size) lead to increasing overall costs. The ability to produce smaller feature sizes by fine-tuning equipment is dependent on the semiconductor manufacturing process used and the capability of the engineers operating the equipment.

produce integrated circuits that are one generation or less behind current state of the art.<sup>19</sup> Figure 1 shows how the technology gap between the United States and China has narrowed since 1986.

**Figure 1: Semiconductor Manufacturing Technology Gap Between China and the United States (feature size measured in microns)**



Note: Complete data for the period between 1986 and 2002 were not available. The time scale was altered to show the years where data were available. Data for 2002 based on estimates. Data points for the years listed are as follows: China--5.00, 3.00, 0.80, 0.35, and 0.18 micron; United States--1.00, 0.35, 0.25, 0.18, and 0.13 micron.

Source: GAO analysis of data provided by semiconductor manufacturing facilities in China; the director of the Computer Aided Life Cycle Engineering Electronics Products and Systems Center, University of Maryland; Intel Corporation; and the International Technology Roadmap for Semiconductors.

<sup>19</sup>A microelectronics expert at the Naval Research Laboratory stated that worldwide state-of-the-art commercial production was 0.18 micron in 2001. Industry considered 0.13 micron state of the art in 2001. Although China is now capable of producing close to state-of-the-art technology, its current domestic demand for these integrated circuits is low (about 13 percent of China's demand is for semiconductors with feature sizes between 0.18 and 0.5 microns, while 87 percent is for older technology between 0.6 and 6 microns).



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## Acquiring Semiconductor Technology and Related Know-How Is a Priority of the Chinese Government

China's stated goal is to become self-sufficient in the production of semiconductors for its domestic market and to develop technology that is competitive on the world market. This goal is being pursued for economic and national security reasons and is directed by a series of 5-year economic plans, and projects focused on high-technology industries. China has pursued a number of strategies to acquire the technology to meet its current and future semiconductor needs, including procuring semiconductors on the open market for both commercial and military uses and developing a domestic manufacturing capability. China also recognizes the importance of foreign investment and has instituted numerous incentive programs, which include free use of land and low taxes, to attract some of the world's leading semiconductor manufacturers and equipment suppliers. To encourage domestic innovation, China has constructed 53 "Silicon Valley"-style, high-technology development zones. In addition, China is cultivating the human capital to operate and manage semiconductor design and manufacturing facilities, in part from students returning to China after earning degrees at U.S. universities in semiconductor-related subjects. It also is acquiring expertise from foreign semiconductor manufacturers who provide their Chinese employees with advanced training and establish research and development facilities in China.

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## Foreign Partners Improve China's Integrated Circuit Manufacturing Capability

The narrowing gap between U.S. and Chinese technology stems from both the Chinese government's concentrated effort to develop its semiconductor manufacturing capabilities and the direct involvement of foreign integrated circuit manufacturers. Since 1995, China has substantially increased its semiconductor manufacturing capabilities through joint ventures and foreign direct investment. Five out of China's eight newest major integrated circuit manufacturing facilities were established as joint ventures; the other three are wholly-owned entities funded with foreign capital. (See table 1 for details on the level of technology incorporated at each facility and the level of Chinese ownership.)

**Table 1: Newest Semiconductor Manufacturing Facilities in China (as of February 2002)**

Facility	Year founded	Minimum feature size in micron	Wafer size (diameter)	Approximate wafers/month	Foreign/ Chinese partner	Percent Chinese ownership
Advanced Semiconductor Manufacturing Corporation	1988	0.6	5" & 6"	40,000	Philips (Netherlands)/Chinese government	62
Shanghai Belling	1988	0.8	4" & 5"	13,300	Alcatel (Belgium)/Shanghai Bell & Shanghai municipal government	64
Shougang NEC	1991	0.35	6"	8,000	NEC (Japan)/Chinese government	51
Motorola Corporation	1996	0.25	8"	24,000 <sup>b</sup>	Motorola (U.S.)/none	0
Shanghai Hua Hong NEC	1996	0.35	8"	20,000	NEC (Japan)/Shanghai and Chinese government	71
Central Semiconductor Manufacturing Corporation	1997	0.3	5" & 6"	12,000	CSMC(Hong Kong)/Chinese government	49
Grace Semiconductor Manufacturing Corporation <sup>a</sup>	2000	0.25	8"	25,000 <sup>b</sup>	International/none	0
Semiconductor Manufacturing International Corporation <sup>a</sup>	2000	0.18	8"	45,000 <sup>b</sup>	International/none	0

<sup>a</sup>Both Grace and Semiconductor Manufacturing International are managed by Taiwanese nationals. Funding for these companies comes from multiple international sources.

<sup>b</sup>These are planned production levels; none of the companies are currently producing at full capacity.

Source: Semiconductor manufacturing firms listed in the table.

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These joint ventures and wholly foreign owned semiconductor manufacturing facilities provide China with access to more advanced technology than it previously had or could produce on its own. U.S. companies have participated in these joint ventures. This trend in joint ventures and foreign direct investment is likely to continue since there are plans to construct an additional 10 to 20 advanced semiconductor manufacturing facilities in China by 2005 at an estimated cost of over \$1 billion per facility. The Semiconductor Industry Association estimates that China will become the world's second largest market for integrated circuits by 2010, and that the market for semiconductor manufacturing equipment in China will grow to \$7 billion by 2003. Applied Materials, which is based in Santa Clara, California, and is the world's largest manufacturer of semiconductor equipment, estimates that 20 percent of its revenue in the next decade will be derived from sales to China.<sup>20</sup> Moreover, since the quality of semiconductor manufacturing equipment produced in China is not high enough to use in modern facilities, Chinese companies have established joint ventures with foreign semiconductor equipment manufacturing companies in an effort to improve the semiconductor manufacturing equipment constructed in China. Figure 2 shows one of China's newest semiconductor manufacturing facilities, Hua Hong NEC in Shanghai.

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<sup>20</sup>Applied Materials' total revenue in 2001 was \$7.34 billion. Approximately \$147 million or 2 percent of this revenue was generated by sales to manufacturing facilities in China.

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**Figure 2: Shanghai Hua Hong NEC Semiconductor Manufacturing Facility  
(Completed in 2001)**



Source: Shanghai Hua Hong NEC.

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In addition to improving China's semiconductor manufacturing technology, the joint ventures and wholly foreign owned facilities have increased the overall volume of integrated circuits produced in China by supporting the country's migration to larger silicon wafers.<sup>21</sup> This shift allows China to produce greater numbers of integrated circuits and thus reduce their cost per unit. Grace, Semiconductor Manufacturing International, and Motorola will add an additional 94,000 8-inch wafers per month to China's overall production capacity once their facilities are fully operational in early 2002. According to the State Department, when these new fabrication facilities are operational, they will "multiply by several times China's current production capacity, putting [it] on the map both technologically and in terms of capacity in the global market."<sup>22</sup> Further, several of these modern manufacturing facilities are designed to produce custom-made semiconductors for any customer. Consequently, they provide China's industry and military with a new source of custom-made integrated circuits that are not subject to foreign export controls.<sup>23</sup>

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Improvements in  
Semiconductor  
Manufacturing Industry  
Assist China's Military  
Modernization

According to a senior Defense Department official, a cutting-edge domestic semiconductor industry supports military modernization in China.<sup>24</sup> According to this official, China's military modernization program appears to be focusing on 'pockets of excellence,' where advances in select technologies can be leveraged for disproportionate benefit in a potential conflict. Several such 'pockets' include: preemptive long-range precision strike capabilities; information dominance; command and control; and integrated air defense. In support of these efforts, Beijing has identified the development of an indigenous semiconductor industry as one of its highest priorities. This official added that China's increasing emphasis on the

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<sup>21</sup>Approximately twice as many integrated circuits can be produced on a silicon wafer with an 8-inch diameter compared to a 6-inch wafer; 2.5 times the number of integrated circuits can be produced on 12-inch wafer compared to an 8-inch wafer.

<sup>22</sup>The new fabrication facilities primarily use 8-inch wafers. In contrast, the majority of China's older manufacturing facilities use 4-inch, 5-inch, and 6-inch wafers.

<sup>23</sup>Manufacturers we spoke to in Taiwan and China stated that they would manufacture small numbers of wafers (3-25) for a single customer.

<sup>24</sup>January 17, 2002, statement of the deputy under secretary of defense for technology security and counterproliferation before the U.S.-China Commission.

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development of integrated circuits “will have direct application in future military systems, for example, advanced phased-array radar.”<sup>25</sup>

Moreover, advanced semiconductor production facilities improve China’s military industrial base by providing a conduit for technology transfer, including transfer of technical specifications, production and process technology, and management and marketing skills that can aid indirectly in military production. According to the Defense Department experts we consulted, these facilities provide China with a domestic supply of integrated circuits that are useful in a broad range of applications including command, control, communications, surveillance, and missile guidance equipment that is less vulnerable to foreign disruption during a protracted conflict.

The most sophisticated facilities in China are capable of producing semiconductors with feature sizes that are more advanced than those used in some of the United States’ most advanced weapons.<sup>26</sup> For example, the U.S. Air Force’s new F-22 advanced tactical fighter is now undergoing pre-production testing after a decade of development. The aircraft’s avionics<sup>27</sup> rely on an Intel i960MX microprocessor that has a feature size of 0.8 micron. In terms of feature size, the i960MX processor is at least four technology generations behind the integrated circuits that China is capable of producing today.<sup>28</sup>

According to defense experts, the semiconductor manufacturing technology China has acquired will enable it to produce components to enhance current and future weapon systems. However, having the components does not guarantee that China will be able to produce complete weapons systems. The experts note that China has experienced

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<sup>25</sup>Phased-array radar uses a set of many small stationary radar antennas configured to create a narrow radar beam that can be electronically steered in any direction in a fraction of a second to track missiles.

<sup>26</sup>The Department of Defense considers semiconductor manufacturing capability more advanced than 0.7 micron to be military critical.

<sup>27</sup>Avionics refers to three major classes of airborne equipment—communications, navigation, and interrogation. The integrated avionics system is a major feature of the F-22, permitting the pilot to have substantially better control of the information regarding the surrounding environment.

<sup>28</sup>The i960MX processor went out of commercial production in 1999. It has a rating of 5 to 10 million theoretical operations per second and runs at a speed of 20 megahertz.

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problems translating theory and design into reliable weapons systems. They also note that China's defense industry faces technical, structural, and other barriers that impede its ability to absorb and utilize advanced technologies for weapons production. For example, China's defense industry lacks many of the basic skills, such as making complex systems work together, necessary to fully utilize acquired technologies. These experts also note that the highly compartmentalized and risk-adverse hierarchical structure of China's defense industry make it difficult for various branches of the industry to collaborate on weapons design or extract greater benefits from technology.

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## Wassenaar Arrangement Has Not Affected China's Ability to Acquire Advanced Semiconductor Manufacturing Equipment

The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies has not affected China's ability to obtain semiconductor manufacturing equipment primarily because the United States is the only member of the Wassenaar Arrangement that considers China's acquisition of semiconductor manufacturing equipment a cause for concern. One of the principal goals of the arrangement is to prevent "destabilizing accumulations" of advanced dual-use goods and technologies through the reporting of export information by its members. Transparency, through exchanging information and sharing views, is the sole means by which the arrangement tries to achieve its goals. Yet, under existing Wassenaar agreements, there are no commitments to provide information on exports for 97 percent of all electronics-related items, including semiconductor manufacturing equipment, covered by the arrangement. In addition, a large-scale decontrol of these items has occurred since the end of the cold war.

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## United States Is the Only Member Concerned About China

There is a broad consensus among Wassenaar members that the export of an item covered by the arrangement should be denied only if it is critical for military purposes and destined for a state whose actions may undermine regional or international security and stability. The United States is the only member that considers the relationship between semiconductor manufacturing equipment and military end uses sufficiently critical and considers China's acquisition of this technology a potential threat to regional or international stability. We found that European, Japanese, and U.S. export control authorities license sales of semiconductor manufacturing equipment to China that is at least two generations more advanced than the threshold stipulated in the Wassenaar and Commerce

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lists (0.50 micron) and three generations more advanced than what the Defense Department considers military critical (0.70 micron).

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## Wassenaar Reporting Does Not Provide Enough Information to Assess Accumulations

Member states have agreed to exchange only limited information on items covered by the Wassenaar Arrangement. Thus, arrangement reporting data do not provide sufficient information to determine whether countries are accumulating advanced dual-use semiconductor manufacturing goods and technologies.<sup>29</sup> The Wassenaar Arrangement's activities focus on the regular review and updating of technical parameters for three lists of dual-use items—basic, sensitive, and very sensitive—for which there are varying reporting commitments. In general, no export information is shared for 76 percent of all listed items. No export information is shared among members for 97 percent of the electronics-related items covered by the arrangement.<sup>30</sup> (See app. II for information on Wassenaar reporting commitments.) Metal organic chemical vapor deposition equipment is the only type of semiconductor manufacturing equipment that is defined as sensitive and thus subject to arrangement reporting commitments for approved exports. This equipment has a wide range of capabilities, some of which are applicable to military uses. However, we found that the reporting information on approvals for such equipment lacks enough detail to shed much light on its capabilities or intended end use and is of little practical use for determining the semiconductor manufacturing capability of the country to which the equipment is exported.

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<sup>29</sup>The Final Report issued in April 2001 by the Study Group on Enhancing Multilateral Export Controls for U.S. National Security, a joint project of the Henry L. Stimson Center and the Center for Strategic and International Studies, came to a similar conclusion. A Department of Commerce study, *U.S. Commercial Technology Transfers to the People's Republic of China*, January 1999, also concluded that export control reporting systems are an ineffective mechanism for tracking accumulations of technology and capabilities.

<sup>30</sup>There are nonbinding arrangements to report export information for just 4 out of the 127 items (3.1 percent) in Category 3 (electronics). More specifically, there are nonbinding arrangements to report export information for just 1 out of 26 items or 3.8 percent in Category 3B (equipment) and no arrangements to report information on any Category 3C (materials) items.



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In addition, the time lapse between exports of items and the reporting of these transfers further reduces the value of the minimal reporting information. Aggregate sensitive and very sensitive item approval information is reported twice a year.

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## The Arrangement Does Not Have a “No Undercut” Rule

The Wassenaar Arrangement lacks a “no undercut” rule, under which a Wassenaar member would agree not to permit the export of any listed item(s) that had been, within a specified period, officially denied an export license by another member. According to a senior Wassenaar Arrangement official, implementing a no undercut rule would be the only realistic way to relieve competitive pressures to approve certain exports. For example, the United States denied the sale of an advanced metal organic chemical vapor deposition machine—which can be used to manufacture compound semiconductors for advanced military systems such as missiles and satellites—to the Hebei Semiconductor Research Institute in China in May 1998 because of concerns about its possible diversion for military uses.<sup>31</sup> A German company sold equivalent equipment to the same end user. The practical effect of the U.S. denial was the loss of a multimillion-dollar sale by Emcore Corporation and the gain of a sale by Germany-based Aixtron GmbH.<sup>32</sup> In response to this situation, the United States formally registered its displeasure with the German government through a diplomatic démarche.<sup>33</sup>

Our work identified other examples of equipment and materials being sold to end users to whom the United States had previously denied export licenses. For example, the Institute for Semiconductors in Beijing (see fig. 3) and the Nanjing Electronic Device Institute both have German-made metal organic chemical vapor deposition equipment.<sup>34</sup> The U.S. government

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<sup>31</sup>Information provided by Somerset, New Jersey-based Emcore Corporation.

<sup>32</sup>Emcore Corporation’s application to sell metal organic chemical vapor deposition equipment to China was denied by the U.S. government on May 9, 1998.

<sup>33</sup>A démarche is a diplomatic protest or representation. The United States has démarched the Germans several times on this issue.

<sup>34</sup>Information obtained from the institute in Beijing and the suppliers of the equipment. The operating parameters of the German-made equipment at these facilities exceed the parameters deemed military critical on the Department of Defense Military Critical Technologies List. The United States has also licensed the sale of equipment with similar operating parameters to other Chinese entities.

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has determined that exports of semiconductor manufacturing equipment and materials to these institutes are detrimental to U.S. national security interests.

Figure 3: German Metal Organic Chemical Vapor Deposition Equipment at the Institute of Semiconductors, Beijing



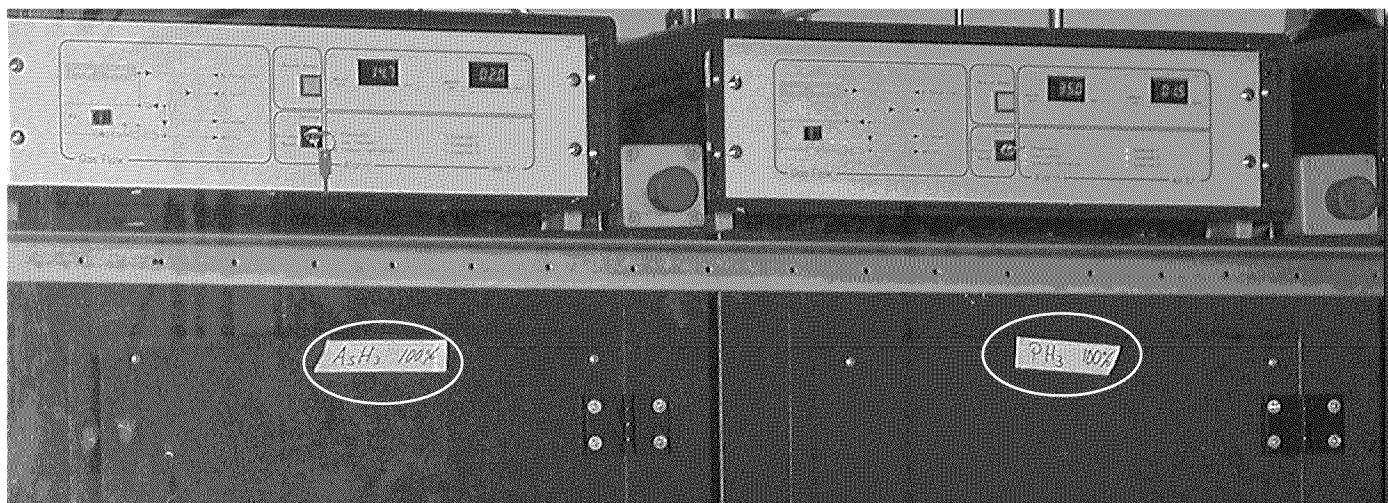
Source: GAO.

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The United States has also denied the sale of arsine and phosphine gases to the Institute of Semiconductors in Beijing for national security reasons.<sup>35</sup> However, as shown in figure 4, during our visit to the institute we found that the institute was using these same gases in its manufacturing process.

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**Figure 4: Controlled Arsine and Phosphine Gases in Use at the Institute of Semiconductors, Beijing**



Source: GAO.

Note: Highlighted areas indicate gas mixtures (arsine on the left and phosphine on the right) currently being used in the production of semiconductors.

According to an institute official, due to U.S. export controls, the gases the institute uses are purchased from European and Japanese companies. GAO did not independently verify this statement. It should be noted that the Commerce Department has charged a company for illegally exporting chemicals to China, including the chemicals in question.

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<sup>35</sup>These gases are controlled by 15 C.F.R., Part 774, Supp.1, Category 3C of the Commerce Control List. Information on the denial of the license was provided by the exporter of the gases.

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## Large-Scale Decontrol Raises Questions About Relevancy

Since the end of the cold war, there has been a trend toward the large-scale decontrol of dual-use goods and technologies, including semiconductor manufacturing equipment and materials, which has raised questions within government and industry about the Wassenaar Arrangement's relevance as an export control mechanism. For example, 50 percent of the adopted proposals from 1997 through 2000 for Categories 3B and 3C liberalized controls on items or decontrolled items. Only 33 percent of the proposals added new controls. The remaining proposals clarified the text of the lists of controlled items.

The increasingly blurred lines between civilian and military technology are an important factor leading to more decontrol, according to officials we interviewed. More and more advanced goods and technologies are considered dual-use. For example, gallium arsenide-based integrated circuits used in devices with high frequency and power requirements had only aerospace and military applications in the past. They are now used widely in common consumer devices such as mobile phones.

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## Export Controls on Advanced Semiconductor Manufacturing Technology to China Lack Analytical Basis

Under the Export Administration Regulations pertaining to China, the general licensing policy is to approve applications, with some exceptions. The regulations also state that each license application is to be considered individually, which allows for some assessment of the semiconductor equipment being exported and of end users and end uses. Although the regulations make no reference to the level of technology that can be exported to China relative to the current commercial state of the art, according to policy officials, U.S. practice has been aimed at keeping China at least two generations (about 3 to 4 years) behind global state-of-the-art semiconductor manufacturing production capabilities. However, U.S. agencies have not used the available analytic tools to serve as a basis for this practice or to make decisions on export licenses. Despite the two-generations-behind objective, we found that the United States approves most licenses for exports of semiconductor manufacturing equipment and materials to China. Although these licenses contain a number of conditions stipulating how such equipment can be used, we found that the Commerce Department has not conducted any "end-use" checks on the U.S. semiconductor equipment exported to China to determine whether licensing conditions are being met.

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## Industry Notes Lack of Clarity in Current Export Regulations

U.S. export licensing control policy toward China is broadly described in title 15, sections 742.4(a) and 742.4(b)(7) of the Export Administration Regulations, which state:

- It is the policy of the United States to restrict the export and reexport of items that would make a significant contribution to the military potential of any other country or combination of countries that would prove detrimental to the national security of the United States. (742.4(a))
- For the People's Republic of China, the general licensing policy is to approve [license] applications, except that those items that would make a direct and significant contribution to electronic and antisubmarine warfare, intelligence gathering, power projection, and air superiority receive extended review or denial. Each application will be considered individually. Items may be approved even though they may contribute to Chinese military development or the end user or end use is military. (742.4(b)(7))

Although the regulations broadly describe U.S. export policy to China, they do not describe the level of technology that can be exported to China relative to the current commercial state of the art. In March 2001, the Commerce Department's undersecretary for export administration and the director of the Technology and Security Directorate of the Defense Threat Reduction Agency told us that the U.S. government's practice, while undocumented, has been to use export controls on semiconductor manufacturing technology to keep China's semiconductor manufacturing industry at least two generations behind commercial state-of-the-art production capabilities. In commenting on a draft of this report, officials from the Departments of Commerce, Defense, and State said this is not U.S. policy. However, in its detailed comments, the Commerce Department contradicted this assertion and stated that certain exports to China are limited to two generations behind state-of-the-art levels to address national security or other concerns related to a particular transaction. Industry officials we interviewed confirmed that this practice exists. They stated that the lack of clear criteria has created a great deal of uncertainty about the export licensing process and raises questions about the rationale for some U.S. government licensing decisions. We found that European, Japanese, and U.S. companies have all exported advanced semiconductor manufacturing equipment to China that allows manufacturing facilities to produce semiconductors that are less than two generations behind commercial state-of-the-art technology.

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## Analysis on Which to Base Policy Objective Is Lacking

We also found that neither the Department of Commerce nor Defense had conducted the analyses that could serve as the basis for an export control policy objective, related export licensing decisions, or U.S. proposals to the Wassenaar Arrangement.

- The Commerce Department has the authority to initiate “foreign availability” assessments that identify foreign sources of items subject to U.S. national security export controls, such as semiconductor manufacturing equipment. These assessments determine if items of comparable quality are available in quantities that would render U.S. export controls on the items ineffective. Commerce Department officials and Semiconductor Equipment and Materials International representatives stated that a foreign availability study has not been conducted since 1987. Industry officials told us that they had not requested these studies, as allowed by the regulations, because the government’s prior effort to complete a study took several years and was outdated at issuance. Industry officials told us that if new studies were conducted and completed in a timely manner, the results would indicate that U.S. export controls on the items studied have been ineffective since all the equipment necessary to manufacture semiconductors can be purchased from non-U.S. sources.
- The Commerce Department conducts studies of the impact of U.S. export controls and sanctions on particular industries and overall U.S. global trade. It conducts these studies because U.S. economic interests are major factors in export control decisions, along with national security and foreign policy concerns. However, we found that the Commerce Department has not studied the impact of export controls on the U.S. semiconductor manufacturing equipment and materials industries.
- The Commerce Department researches technology transfer issues in order to enhance long-term U.S. economic security. In addition, Department of Defense Directive 2040.2 states that the department shall “assess annually the total effect of transfers of technology, goods, services, and munitions on U.S. security, regardless of the transfer mechanisms involved.”<sup>36</sup> We found that neither the Departments of

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<sup>36</sup>Department of Defense Directive Number 2040.2, sections 5.1.7 and 7.1.15, January 17, 1984, reissued incorporating Change 1, July 5, 1985.

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Commerce nor Defense has conducted assessments of the cumulative effect of semiconductor-related technology transfers to China. Further, Department of Defense Directive 2040.2 has not been updated since July 5, 1985, and many of its provisions are centered on the Coordinating Committee for Multilateral Export Controls, the predecessor to the Wassenaar Arrangement.

- The Export Administration Act of 1979 calls for the Defense Department to compile a list of military critical technologies.<sup>37</sup> The Military Critical Technologies List describes the performance parameters of critical technologies that the United States needs to ensure superiority of U.S. military systems.<sup>38</sup> The list is intended to serve, among other purposes, as the technical foundation for U.S. negotiators in the Wassenaar Arrangement, and as a technical reference guide for the Departments of Commerce, Defense, Energy, State, and Treasury licensing and export control staff. In developing the list, defense and intelligence analysts also make related foreign technology assessments that describe foreign countries' capabilities to produce each of the listed technologies.<sup>39</sup> Despite major advances in semiconductor-related technology in the United States and in foreign countries, the Defense Department has not substantively updated the Military Critical Technologies List pertaining to semiconductor equipment and materials since 1996.

Without these analyses and assessments, the Departments of Commerce, Defense, and State are making licensing decisions and U.S. proposals to Wassenaar without complete and up-to-date information. According to the Departments of Defense and State, the export licensing community is kept informed by frequent industry briefings, intergovernmental contacts, the international press, and information exchanges among Wassenaar Arrangement members. Although the information obtained through these methods is useful, it is not an adequate substitute for formal agency analysis.

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<sup>37</sup>50 U.S.C. App. section 2404(d)(2).

<sup>38</sup>The technology list covers 18 categories including electronics, under which semiconductors and semiconductor manufacturing equipment and materials fall.

<sup>39</sup>The technology assessments are foreign capability assessments and do not constitute findings of foreign availability covered by Commerce Department foreign availability assessments.



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## Most Export Licenses for Semiconductor Manufacturing Equipment and Materials Are Approved

We found the majority of export license applications for semiconductor manufacturing equipment and materials for China are approved. From fiscal year 1997 through fiscal year 2000, 64.6 percent of export licenses for semiconductor manufacturing equipment (Category 3B) were approved, and 78.3 percent of export licenses for semiconductor manufacturing materials (Category 3C) were approved. Other data indicate that export license denials have not had a major economic impact on the industry.<sup>40</sup> The U.S. government reviewed nearly \$1.6 billion worth of semiconductor manufacturing equipment and materials licenses for export to China from fiscal year 1997 through fiscal year 2000; only 0.4 percent and 0.5 percent of equipment and materials licenses, respectively, were denied as measured by dollar value.<sup>41</sup>

The approved licenses typically contain a number of conditions that stipulate the characteristics (such as feature size) of the integrated circuits that can be produced, the types of integrated circuits that equipment should not be used to produce, and the customers who can or cannot purchase the integrated circuits produced with the licensed equipment, among other things. The conditions are designed to deter the end user from using the equipment inappropriately. Without periodic monitoring, there is no way to verify compliance. Although monitoring is supposed to be accomplished through end-use checks conducted by U.S. government personnel, we found that the U.S. officials in China tasked with this job have not conducted any of these checks on semiconductor manufacturing equipment in the last 5 years. In testimony before the U.S. China Commission on January 17, 2002, the Commerce Department's assistant secretary of export enforcement stated that the schedule for conducting end-use checks is dictated by the Chinese government.<sup>42</sup> This situation has

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<sup>40</sup>Semiconductor Equipment and Materials International maintains that as license applications for China increase, the inability to quickly and predictably obtain license approvals could have a significant negative impact on the industry.

<sup>41</sup>Licenses can also be returned to applicants without action. An export license application is returned without action if the applicant does not respond to Department of Commerce requests for additional information within 20 days. During the fiscal year 1997 through fiscal year 2000 period, 26.1 percent of Category 3B and 13 percent of Category 3C license applications were returned without action. As measured by dollar value, 0.8 percent of Category 3B and 27.8 percent of Category 3C license applications were returned without action.

<sup>42</sup>End-use checks in China are conducted based on an end-use visit arrangement negotiated between the U.S. and Chinese governments in 1998.

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caused a number of problems. Specifically, most of the end-use checks that the United States has been allowed to conduct have been on high-performance computers that are no longer controlled due to the liberalization of export controls. In addition, due to delays caused by the Chinese government's scheduling, 700 outstanding checks remain to be completed, checks on items other than high-performance computers continue to "languish," and the Commerce Department is unable to focus its efforts on the checks it considers the most strategic.

Despite the overall high approval rates for electronics goods and technologies, there are a few cases where licensing denials did cost some U.S. companies sales worth several million of dollars. We asked companies that are members of the semiconductor equipment and materials trade association to provide examples of cases where export license denials resulted in sales lost to foreign competitors. Of the six cases they identified, we were able to verify two. In May 1998, the Commerce Department denied an export license to Emcore Corporation of Somerset, New Jersey, to sell a metal organic chemical vapor deposition machine to the Hebei Institute of Semiconductors. The institute later purchased a similar machine from Aixtron GmbH of Aachen, Germany.<sup>43</sup> In 2001, Hayward, California-based ETEC lost the sale of a mask pattern generating machine (ALTA 3000) to Shanghai-based Semiconductor Manufacturing International Corporation. Due to delays in the license approval process, the firm canceled its ETEC order and purchased a machine from Micronic of Taby, Sweden. The Commerce Department later approved the sale of a more advanced machine (ALTA 3500) to Semiconductor Manufacturing International Corporation.<sup>44</sup>

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## Conclusions

The current export control system has not effectively slowed China's ability to obtain billions of dollars worth of advanced semiconductor equipment as part of its national strategy to modernize its semiconductor industry and thus needs to be reexamined. The success of export controls is predicated on a nation's ability to control a particular form of technology or to

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<sup>43</sup>Information on the denial of this license was provided by Emcore.

<sup>44</sup>The ALTA 3000 is used to manufacture products with a feature size of 0.35 micron, while the ALTA 3500 manufactures products with a feature size of 0.25 micron. All information concerning ETEC, Semiconductor Manufacturing International Corporation, and Micronic, including dispositions of licenses, was provided by ETEC and Semiconductor Manufacturing International Corporation.

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multilateralize binding controls. However, U.S. agency efforts to control this technology have been complicated by the globalization of the industry and foreign competitors' views that transfers of this technology to China are not a matter for concern. In addition, Wassenaar Arrangement reporting does not provide enough information to allow member countries to assess whether destabilizing accumulations of these and related dual-use goods and technologies are occurring. While U.S. export regulations broadly describe export licensing policy to China, they lack criteria describing the level of semiconductor manufacturing technology that can be exported to China relative to the current state of the art. This has led industry to perceive that semiconductor manufacturing equipment sales to China are subject to an ad hoc system of controls. Under the current approach, the U.S. government continues to require licenses for semiconductor manufacturing equipment without 1) adequate consideration of the impact of the global market forces that are undermining its ability to control this technology, 2) the cumulative effect of the transfer of this technology on U.S. national security, and 3) clear justification for why the current control parameters are maintained or how they contribute to slowing the transfer of this equipment to China. Without an updated assessment, U.S. policymakers may find it increasingly difficult to justify licensing decisions and to strike the appropriate balance between national security risks and the economic interest in promoting sales of high-technology goods to China.

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## Recommendations for Executive Action

To improve the effectiveness of the U.S. export control system, we recommend that the secretary of commerce work with the secretary of defense and the secretary of state to reevaluate, clarify, and document export policy on semiconductor manufacturing equipment and materials. These actions should include:

1. conducting assessments of foreign availability, the technical parameters necessary to ensure critical U.S. military capabilities, the impact of export controls on U.S. industry, and the overall national and economic security implications of China's ability to import, produce, and develop advanced semiconductor-related technology;
2. developing new export controls if the technology needs to and can be controlled, and updating related regulations and policy documents including the Military Critical Technologies List and Department of Defense Directive 2040.2. If the technology cannot be controlled using

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export controls, develop alternative means for protecting U.S. security interests; and

3. communicating the results of the assessments and the options for controlling the technology and protecting U.S. security to the U.S. Congress and industry.

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## Agency Comments and Our Evaluation

We received written comments on a draft of this report from the Departments of Commerce, Defense, and State that are reprinted in appendixes III, IV, and V.

The Departments of Commerce, Defense, and State disagreed with our analysis and conclusions and said our report is based on a flawed premise that U.S. controls on semiconductor manufacturing-related items exported to China stem from a policy of trying to keep Chinese industry at least two generations behind state-of-the-art semiconductor manufacturing facilities. These agencies said that U.S. policy for why and how these items should be controlled can be found in the Export Administration Regulations and that this policy specifies a case-by-case review. The Commerce Department said that no policy-level official at the Commerce Department informed GAO of the two-generations-behind policy. The State Department also asserted that, contrary to our report findings, the current U.S. export licensing process does consider the nature and extent of foreign availability of semiconductor manufacturing equipment and the cumulative effect of those exports to China, as well as the potential risks to U.S. national security. The State Department asserted that these efforts are sufficient to meet the intent of the draft report's recommendations concerning establishing a sound, analytical basis for current policy. The Commerce Department also noted that no semiconductor equipment producer or industry association has requested a foreign availability assessment.

We agree with the Departments of Commerce, Defense, and State that a description of the U.S. government's export control policy toward China is found in the Export Administration Regulations. We added some additional information to the report to better describe this policy and to make a clearer distinction between policy and practice as the current regulations make no reference to the level of semiconductor manufacturing technology that can be exported to China relative to the current commercial state of the art. We found that the executive branch practice was aimed at keeping China two generations behind the U.S. semiconductor manufacturing industry. On March 1, 2001, the under

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secretary for export administration (a policy-level official) described this practice and reconfirmed it in a follow-up January 2002 meeting with GAO after he left office.

Moreover, in commenting on our draft report, the Commerce Department described this practice, noting that “certain exports of semiconductor manufacturing equipment to China are limited to two generations behind state-of-the-art levels to address national security, or other concerns related to a particular transaction. On a number of occasions, however, exports of more sophisticated equipment to wholly-owned subsidiaries of U.S. companies located in China have been approved.” In a January 17, 2002, hearing before the U.S.-China Commission, the president of the Semiconductor Industry Association also discussed this practice. He testified that “As a result of the ready availability of SEM [semiconductor production equipment and materials] globally, the U.S. policy objective of using export controls to keep China’s indigenous semiconductor production two generations behind the state of the art is not being met, yet the controls remain, hampering U.S. SEM suppliers and their ability to remain global leaders.” U.S. industry officials complain that the lack of clearly articulated criteria creates uncertainty about the export licensing process and raises question about U.S. export policy toward China. That is why we are recommending that this issue be reevaluated, clarified, and documented. We are not suggesting that the “two-generations-behind” objective is the appropriate criterion; rather, we are recommending that the executive branch devise appropriate criteria once the supporting analysis has been completed and documented.

Regarding the Departments of Commerce, Defense, and States’ comments that the current export licensing process is based on a sound, analytical framework, we found that a U.S. government foreign availability analysis of semiconductor manufacturing equipment has not been completed since 1987. Further, the U.S. government has not conducted studies of the cumulative effect of the export of advanced semiconductor manufacturing equipment and materials to China on U.S. national security.

The Department of Defense also questioned whether China’s semiconductor industry has advanced as far as our analysis suggests. In particular, the department disputed our analysis indicating that China is one generation of technology behind the United States. The Defense Department cited a November 2001 press release issued by the Semiconductor Manufacturing International Corporation (SMIC) to support its conclusion. We met with the senior management team of this

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corporation during our visit to China in June 2001 and verified the information we presented in our report in follow-up discussions with company officials. The Department of Defense also cited a 2001 RAND Corporation study that discusses developments in China's microelectronics industry to support its assessment of China's current semiconductor manufacturing capabilities. The study was based on secondary sources utilizing 1997 industry data. Our analysis was based on 2001 primary data collected directly from semiconductor manufacturing industry officials in China.

The Departments of Commerce and Defense also said that, due to confidentiality provisions of current law (e.g., section 12(c) of the Export Administration Act of 1979, as amended), public disclosure of information regarding individual license applications is not authorized. We discussed these issues with agency officials and assured them that all company-specific examples we used in our report were obtained from public sources or the companies and organizations mentioned in the report.

The Departments of Commerce, Defense, and State also commented that the report presented no evidence that the semiconductor manufacturing facilities constructed in China provided any benefit to China's military. However, in a January 17, 2002, hearing before the U.S.-China Commission, the deputy undersecretary of defense for technology security and counterproliferation affirmed our observation. This official noted that "China's modernization program appears to be focusing on pockets of excellence, where advances in select technologies can be leveraged for disproportionate benefit in a potential conflict. Several such pockets include: preemptive long-range precision strike capabilities; information dominance; command and control; and integrated air defense. In support of these efforts, Beijing has identified the development of an indigenous microelectronics industry as one of its highest priorities. A cutting-edge domestic microelectronics sector will support both military and commercial modernization in China. China's increasing emphasis on the development of very large-scale integrated circuits will have a direct application in future military systems, for example, advanced phased-array radars."

Additional information was added to the report to clarify specific points. However, the comments provided by the Departments of Commerce, Defense, and State provide no basis for altering the findings, conclusions, or recommendations contained in the report.

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## Scope and Methodology

To describe China's present semiconductor manufacturing capability, we met with and reviewed studies and analyses prepared by experts from academia, industry, the intelligence community, and the Departments of Commerce, Defense, and State in Washington, D.C., and Beijing, China. In addition, we met with officials from Advanced Semiconductor Manufacturing Corporation, Central Semiconductor Manufacturing Cooperation, Grace Semiconductor Manufacturing Corporation, Motorola Tianjin, Semiconductor Manufacturing International Corporation, Shougang Electronics NEC, Hua Hong NEC, and DuPont Photo Masks Incorporated in China. As part of this work, we toured the manufacturing facilities of Advanced Semiconductor in Shanghai, China, and Motorola in Tianjin, China. Finally, we met with officials and toured the facilities of the Chinese Academy of Sciences' Institute of Semiconductors in Beijing, China. In addition, to further understand semiconductor research and development and associated manufacturing processes and applications, we visited Semiconductor Materials Technology International in Austin, Texas, and the Sandia and Lawrence Livermore National Laboratories in Albuquerque, New Mexico, and Livermore, California, respectively; the Naval Research Laboratory in Washington, D.C.; the Defense Microelectronics Activity in McClellan, California; the Defense Advanced Research Projects Agency in Arlington, Virginia; and BAE Systems in Manassas, Virginia.

To analyze how the Wassenaar Arrangement has affected the transfer of semiconductor manufacturing equipment and materials to China, we met with representatives of the Departments of Commerce, Defense, and State and an export control expert from the Center for International Trade and Security in Washington, D.C. In China, we met with officials from the Ministry of Foreign Trade and Economic Cooperation in Beijing and the Trade and Industry Department of the government of Hong Kong. Further, we spoke to the director of the New York office of the Japan External Trade Organization in Washington, D.C. We also met with officials from the U.S., Russian, and Japanese Missions to the Wassenaar Arrangement and staff members of the Wassenaar Arrangement Secretariat in Vienna, Austria. We analyzed information provided by the Wassenaar Arrangement's Secretariat, including the Wassenaar Arrangement's Initial Elements, controlled items lists, and export approval and denial reports, to determine whether the arrangement's reporting mechanisms could be used to identify trends in the export of semiconductor equipment and materials and other dual-use technology from 1996 through 2000. Finally, we analyzed trend data describing the disposition of proposals from the United States and

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other members of the Wassenaar Arrangement for 1996 through 2000. We did not verify the data obtained from the Wassenaar Arrangement's Secretariat.

To assess the analytical basis for U.S. export control policy pertaining to the export of semiconductor equipment and materials to China, we met with officials from the Departments of Commerce and State in Washington, D.C., and Beijing, China, and the Defense Department in Washington, D.C., and with officials at the American Institute in Taiwan in Taipei. In addition, we convened panels of representatives from the semiconductor and semiconductor equipment and materials industries in San Jose, California; Hsinchu, Taiwan; and Beijing, China, to obtain their views on U.S. export controls on semiconductors and semiconductor manufacturing equipment and materials. These panels included representatives from Advantest, Applied Materials, Emcore, ETEC, Hermes Systems, Hewlett-Packard, Intel, International Business Machines, KLA-Tencor, National Semiconductor, NEC, Novellus, Texas Instruments, Ultratech Stepper, and Varian Semiconductor Equipment. In addition, we met directly with major U.S. and Taiwanese firms including Advanced Micro Devices, Applied Materials, Intel, Motorola, Silicon Laboratories, Silicon Valley Group, Taiwan Semiconductor Manufacturing Company, United Epitaxy Company, United Microelectronics Corporation, and VIA Technologies Incorporated. We also met with representatives of the Semiconductor Industry Association in San Jose, California; Semiconductor Equipment and Materials International in Washington, D.C., San Jose, California, and Hsinchu, Taiwan; the Taiwanese Semiconductor Industry Association in Hsinchu, Taiwan; and the United States Information Technology Office in Beijing, China; and the attorneys for the industry associations—Dewey Ballantine in Washington, D.C. In addition, we analyzed license processing and approval information from the Commerce Department's Export Control Administrative Support System. Finally, we attended Commerce Department Information System Technology Advisory Committee meetings in San Diego, California, and Washington, D.C. Statements in the report about foreign laws and regulations were derived from secondary sources.

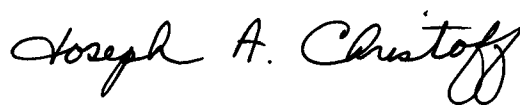
We performed our work from February 2001 through January 2002 in accordance with generally accepted government auditing standards.



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Please contact me at (202) 512-8979 if you or your staff have any questions concerning this report. Other GAO contacts and staff acknowledgments are listed in appendix VI.

Sincerely yours,

A handwritten signature in black ink that reads "Joseph A. Christoff". The signature is written in a cursive style with a large, stylized "J" and "C".

Joseph Christoff  
Director  
International Affairs and Trade

# Reasons for Controlling Dual-Use Goods and Technologies

Export controls on dual-use items are maintained for national security and foreign policy reasons.<sup>45</sup> Each export control regulation is governed by at least 1 of 13 specific concerns. (See figure 6 for a list of the 13 reasons for controlling dual-use goods.)

**Figure 5: Reasons for the Control of Dual-Use Goods and Technologies**

Reasons for Control	
✓	Antiterrorism
✓	Chemical and biological weapons
✓	Crime control
✓	Chemical Weapons Convention
✓	Encryption items
✓	Firearms Convention
✓	Missile technology
✓	National security
✓	Nuclear nonproliferation
✓	Regional stability
✓	Short supply
✓	Computers
✓	Significant terms

Source: 15 CFR section 738.2

The Export Administration Regulations establish the framework for regulating the exports of dual-use items by identifying the characteristics and capabilities of items that may require export licenses. Exports are

<sup>45</sup>15 C.F.R. Part 734.2, Scope of the Export Administration Regulations.

restricted by item, country, and entity. These characteristics and capabilities are contained in the Commerce Control List, which provides detailed specifications for about 2,400 dual-use items, divided into 10 categories (see table 2 for a list of the 10 categories); each category is subdivided into 5 groups designated by the letters A through E (see table 3 for a list of the 5 groups).

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**Table 2: Commerce Control List Categories**

	<b>Commerce Control List categories</b>
0	Nuclear materials, facilities, and equipment, and miscellaneous
1	Materials, chemicals, “microorganisms,” and toxins
2	Materials processing
3	Electronics
4	Computers
5	Telecommunications and information security
6	Lasers and sensors
7	Navigation and avionics
8	Marine
9	Propulsion systems, space vehicles, and related equipment

Source: 15 C.F.R. section 738.2

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**Table 3: Commerce Control List Category Groups**

	<b>Commerce Control List subcategories</b>
A	Equipment, assemblies, and components
B	Test, inspection, and production equipment
C	Materials
D	Software
E	Technology

Source: 15 C.F.R. section 738.2

Semiconductors and semiconductor manufacturing equipment and materials fall under Category 3 (electronics), with manufacturing

equipment placed in Category 3B (test, inspection, and production equipment) and materials placed in Category 3C (materials).<sup>46</sup> These goods and technologies are controlled most frequently as a tool of U.S. antiterrorism policy, but also, as shown in table 4, to meet nuclear nonproliferation policy objectives, control the spread of missile technology and crime, and address general national security concerns.<sup>47</sup> Exports of semiconductor manufacturing equipment and materials to China are controlled for national security reasons. Table 5 describes the specific equipment and materials that require a license for export to China.

**Table 4: Frequency of Reasons for Control of Category 3 (Electronics) Items**

Subcategory	National security	Missile technology	Antiterrorism	Nuclear nonproliferation	Crime control
A	2	2	17	11	2
B	2	0	4	0	0
C	4	0	5	0	0
D	3	2	7	0	1
E	2	3	8	3	0
<b>Total</b>	<b>13</b>	<b>7</b>	<b>41</b>	<b>14</b>	<b>3</b>

Source: C.F.R. 15, Parts 300 to 799, Commerce and Foreign Trade, 2001.

<sup>46</sup>Category 3B and 3C items are described in 15 C.F.R., Part 774, Supp. 1 of the Commerce Control List as test, inspection, and production equipment and materials, respectively.

<sup>47</sup>See C.F.R. 15 Part 774—The Commerce Control List.

**Appendix I**  
**Reasons for Controlling Dual-Use Goods and**  
**Technologies**

**Table 5: Description of Semiconductor Manufacturing Equipment and Materials Requiring Export License to China**

List number <sup>a</sup>	Description	National security significance	Primary supplier countries
3B001.a.1	Thin layer deposition equipment	Radiation-hardened electronics, space-qualified solar cells, high power radio-frequency devices, infrared focal plane arrays	U.S., Japan
3B001.a.2	Metal organic chemical vapor deposition reactors		U.S., Germany
3B001.a.3	Molecular beam epitaxy equipment		U.S., United Kingdom
3B001.b	Ion implantation equipment	Used for radiation hardened circuitry	U.S., Japan
3B001.c	Plasma dry etching equipment	Needed for all state-of-the-art electronics, commercial or military, enable production of controlled analog-to-digital converters, field programmable logic devices, and application specific integrated circuits <sup>b</sup>	U.S., Japan
3B001.d	Plasma enhance chemical vapor deposition		U.S., Japan
3B001.e	Cluster tools		U.S., Japan
3B001.f.1	Lithography systems		U.S., Netherlands, Japan
3B001.f.2	Mask lithography systems		U.S., Japan, Sweden
3B001.g	Masks		U.S., Japan
3B001.h	Multilayer masks		U.S., Japan
3B002.a	S-parameter testers		U.S., Japan
3B002.b	Integrated circuit testers		U.S., Japan, Germany
3B002.c	Microwave integrated circuit testers		U.S., Japan, Germany
3C001.a	Epitaxial silicon wafers	Potential starting material for devices outlined in metal oxide chemical vapor deposition and molecular beam epitaxy equipment	U.S. Japan, Europe, Taiwan
3C001.b	Epitaxial germanium wafers		
3C001.c	Epitaxial wafers of III/IV compounds		
3C002	Photo resists	Same as for 3B001.c	U.S., Japan, Europe
3C003	Purified metal organics	Gas sources for metal oxide chemical vapor deposition	U.S. Japan, Eurpoe
3C004	Purified gases		

<sup>a</sup>Category number in the Commerce Control List. Some items have been consolidated under one heading for clarity.

<sup>b</sup>These items are controlled under Export Administration Regulations, Part 774, 3A001 and 3A101 or under the International Traffic in Arms Regulations Category XI.

Source: Department of Defense, Commerce Control List.

# Wassenaar Reporting Commitments by List

Type of information	Category / percentage of items within each category		
	Basic / 76.3 percent	Sensitive / 19.3 percent	Very Sensitive / 4.4 percent
Approval information	None	<b>Aggregate</b> <ul style="list-style-type: none"> <li>• Exporting country</li> <li>• Destination country</li> <li>• Control List item number</li> <li>• Brief description of the item</li> <li>• Number of units</li> </ul>	<b>Aggregate</b> <ul style="list-style-type: none"> <li>• Exporting country</li> <li>• Destination country</li> <li>• Control List item number</li> <li>• Brief description of the item</li> <li>• Number of units</li> </ul>
Denial information	<b>Aggregate</b> <ul style="list-style-type: none"> <li>• Exporting country</li> <li>• Destination country</li> <li>• Control List item number</li> <li>• Brief description of the item</li> <li>• Number of licenses denied</li> <li>• Number of units</li> <li>• Reason for the denial (usually formulaic, not specific or detailed)</li> </ul>	<b>Individual</b> <ul style="list-style-type: none"> <li>• Exporting country</li> <li>• Destination country</li> <li>• Control List item number</li> <li>• Brief description of the item</li> <li>• Number of units</li> <li>• Intermediate consignee (name and address)</li> <li>• Ultimate consignee (name and address)</li> <li>• Stated end-use</li> <li>• Reason for denial</li> <li>• Other relevant information</li> </ul>	<b>Individual</b> <ul style="list-style-type: none"> <li>• Exporting country</li> <li>• Destination country</li> <li>• Control list item number</li> <li>• Brief description of the item</li> <li>• Number of units</li> <li>• Intermediate consignee (name and address)</li> <li>• Ultimate consignee (name and address)</li> <li>• Stated end-use</li> <li>• Reason for denial</li> <li>• Other relevant information</li> </ul>
Reporting frequency	<b>Denials</b>  Biannually	<b>Approvals</b>  Biannually  <b>Denials</b>  “Preferably” within 30 days but no later than within 60 days	<b>Approvals</b>  Biannually  <b>Denials</b>  “Preferably” within 30 days but no later than within 60 days

Source: GAO analysis of Wassenaar Initial Elements and the December 1, 2000 list of Dual-Use Goods and Technologies.

# Comments from the Department of Commerce

Note: GAO comments supplementing those in the report text appear at the end of this appendix.



**THE SECRETARY OF COMMERCE**  
Washington, D.C. 20230

JAN 16 2002

Mr. Joseph A. Christoff  
Director  
International Affairs and Trade  
U.S. General Accounting Office  
Washington, D.C. 20548

Dear Mr. Christoff:

Thank you for the opportunity to comment on the draft General Accounting Office (GAO) report entitled, "Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review."

After careful review, we believe that the report accurately highlights a number of the challenges associated with multilateral controls on semiconductor manufacturing equipment and technology. However, the report does not accurately portray the U.S. Government's policy for controlling the export of semiconductor manufacturing equipment and technology to China. Contrary to the report's assertion, the U.S. Government does not seek to use the export licensing process to keep China at least two generations behind global state-of-the-art semiconductor manufacturing capabilities. The U.S. Government's policy for exporting controlled items to China, including semiconductor manufacturing equipment and technology, is clearly set forth in the Export Administration Regulations (15 C.F.R. Section 742.4) and specifies a case-by-case determination of license applications based on specific facts. There is no mention of keeping China two generations behind in semiconductor manufacturing capability.

Enclosed are more detailed comments on the report, including identification of information currently contained in the draft report that may not be publicly released because it is subject to section 12(c) of the Export Administration Act of 1979, as amended.

Thank you again for requesting the Department of Commerce's views on the draft report.

Warm regards,

A handwritten signature in dark ink, appearing to read "D. Evans", is written over the typed name.

Donald L. Evans

Enclosures

**Comments and Recommended Changes  
on the Draft GAO Report  
“Rapid Advances in China’s Semiconductor Industry  
Underscore Need for Fundamental U.S. Policy Review”**

**General Comments**

See comment 1.

The U.S. Government’s policy for licensing items for export to China, including semiconductor manufacturing equipment and technology, is set forth in the Export Administration Regulations (15 C.F.R. Section 742.4(b)(7)). As noted in that section, exports to China will generally be approved unless the items would make a direct and significant contribution to specified military applications. Each license application is reviewed thoroughly by the interagency community with consideration given to the proposed end-users and end-uses and the national security implications of each transaction. While individual agencies may take the state-of-the-art semiconductor level into account in taking positions on specific applications, no policy level official at the Department of Commerce has informed the General Accounting Office (GAO) that it is the U.S. Government’s policy to keep China two generations behind global state-of-the-art semiconductor manufacturing capabilities.

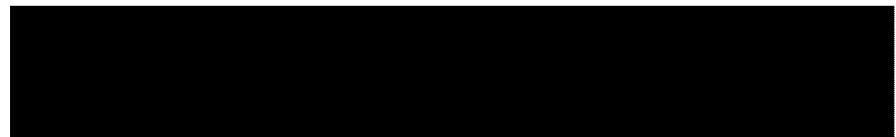
See comment 2.

The report also fails to recognize that the Department of Commerce’s industry analysts, export control specialists, and technical experts track trends in the Chinese semiconductor industry and the activities of foreign competitors in this key sector on an ongoing basis. Commerce analysts factor the information they collect into interagency licensing decisions and multilateral export control negotiations.

See comment 3.

The report recommends that the Department of Commerce undertake a foreign availability review. While the foreign availability provision of the Export Administration Regulations authorizes the U.S. Government to self-initiate a foreign availability assessment, this provision is intended for use and has principally been used by industry to challenge overly restrictive or ineffective export controls. No semiconductor equipment producer or industry association has requested a foreign availability assessment – a fact the report does not mention. There are limited sources of these items, and all producers are members of the Wassenaar Arrangement, so it is unlikely that the foreign availability process would, in and of itself, lead to decontrol. While Wassenaar members have differing views on China, it is a priority of the Administration to do more to harmonize multilateral export control policies and practices.

See comment 4.



See comment 5.

Finally, certain information, which is detailed in the specific comments below, is subject to section 12(c) of the Export Administration Act of 1979, as amended. Such information may not be publicly released.



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Appendix III  
Comments from the Department of  
Commerce

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**Specific Comments**

See comment 6.

Highlights page, third paragraph: This paragraph should be revised to note that U.S. export control policy on licensed exports to China is set forth in the section 742.4 of the Export Administration Regulations (EAR). That policy does not mention keeping China two generations behind.

See comment 7.

Page 3, line 3. Revise to note that the U.S. Government's policy for all licensed exports to China is set forth in section 742.4(b)(7) of the EAR.

*Rationale*: No policy level official at the Department of Commerce informed the GAO that it is U.S. policy to try to keep China at least two generations behind global state-of-the-art semiconductor manufacturing capabilities. License application for such items are reviewed individually with consideration given to the proposed end-uses and end-users and national security implications of each transaction. Certain exports of semiconductor manufacturing equipment to China are limited to two generations behind state-of-the-art levels to address national security, or other concerns related to a particular transaction. On a number of occasions, however, exports of more sophisticated equipment to wholly owned subsidiaries of U.S. companies located in China have been approved.

Now on p. 6.  
See comment 8.

Page 5, line 5: Insert "of 1979," after "Export Administration Act."

Now on p. 6.  
See comment 9.

Page 5, footnote 7: Amend to read: "From August 21, 1994, through November 12, 2000, the Act was in lapse. During that period, the President, through Executive Order 12924, which had been extended by successive Presidential Notices, the last of which was August 3, 2000 (3 C.F.R., 2000 Comp. 397 (2001)), continued the Regulations in effect under the International Emergency Economic Powers Act (50 U.S.C. §§ 1701 - 1706 (1994 & Supp. V 1999)) ("IEEPA"). On November 13, 2000, the Act was reauthorized and it remained in effect through August 20, 2001. Since August 21, 2001, the Act has been in lapse and the President, through Executive Order 13222 of August 17, 2001 (66 Fed. Reg. 44025 (August 22, 2001)), has continued the Regulations in effect under IEEPA."

Now on p. 17.  
See comment 10.

Page 15, line 1: Amend to read: "The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies has not constrained China's ability to obtain semiconductor manufacturing equipment, nor is this a specific objective of this regime. The United States is the only member of the Wassenaar Arrangement that considers China's acquisition of semiconductor manufacturing equipment a cause for concern. As such, it is not a general objective of Wassenaar to restrict exports of semiconductor manufacturing equipment to China."

Now on p. 17.  
See comment 11.

Page 15, line 11: Amend to read: "...there are no commitments to provide information on exports for 97 percent of all electronics-related items, including most semiconductor manufacturing equipment,..."

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Appendix III  
Comments from the Department of  
Commerce

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Now on p. 19.  
See comment 12.

*Rationale:* Individual reporting is required for certain metal organic chemical vapor deposition equipment controlled by Wassenaar under 3.B.1.a.2. of its List of Dual-Use Goods and Technologies. Therefore, the word “most” is inserted in the reference to information on semiconductor manufacturing equipment excluded from reporting.

Page 17, lines 9-10: Delete specific description of machine sought to be exported.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 19.  
See comment 12.

Page 17, lines 12-13: Delete name of Chinese end-user and date of denial.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 19.  
See comment 12.

Page 17, line 17: Delete the name of the U.S. company.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 19.  
See comment 12.

Page 17, lines 23-24: Delete names of Chinese end-users.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 19.  
See comment 12.

Page 17, footnote 30, lines 1-2: Delete information on U.S. company, specific product description, and date.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 21.  
See comment 12.

Page 18, Figure 3 description: Delete name of Chinese end-user.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 22.  
See comment 12.

Page 19, line 2: Delete names of gases.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 22  
See comment 12.

Page 19, line 4: Delete name of Chinese end-user.

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Appendix III  
Comments from the Department of  
Commerce

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Now on p. 22.  
See comment 12.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Page 19, Figure 4: Delete names of gases and Chinese end-user.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 23.  
See comment 13.

Page 20, line 11: At the end of first paragraph, add the following: “The increased activity to modify controls in this area can be attributed to rapid technological advances that necessitate frequent adjustments in levels to maintain controls on that which is strategically responsible and feasible.”

*Rationale:* Some explanation should follow the statistical data to explain why there is a relatively high-level effort to modify Wassenaar export controls in the electronics category. Proposals to remove electronics-related export controls receive the most support because of the regime’s efforts to make controls in this area more reflective of current technology. It is important to note that Wassenaar, unlike other multilateral control regimes, essentially adopted a control list based on out-dated Cold War era technologies. As a result, Wassenaar has been struggling over the past five years to update controls in areas, such as electronics, where technology has been advancing rapidly. The effects of technological trends is a predominant factor in the relaxation of electronics-related controls.

Now on p. 23.  
See comment 14.

Page 21, line 5: Revise to reflect that while some U.S. agency officials may believe there is a ‘two-generation behind’ policy, this is not U.S. Government policy.

*Rationale:* Section 742.4(b)(7) describes the U.S. Government’s policy on licensed exports to China. No Commerce Department policy official informed the GAO otherwise.

Now on p. 24.  
See comment 14.

Page 21, line 19: Same as previous comment.

*Rationale:* Same as previous comment.

Now on p. 24.  
See comment 14.

Page 21, line 24: Amend to read: “... said that although this objective by some in the U.S. Government is “understood” ...”

*Rationale:* Same as above.

Now on pp. 25 and 26.  
See comment 14.

Pages 22-23: This section generally is based on an inaccurate understanding of U.S. Government policy.

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**Appendix III**  
**Comments from the Department of**  
**Commerce**

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Now on p. 28.  
See comment 15.

Page 23, line 27-28: Delete date and name of U.S. company.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 28.  
See comment 15.

Page 24, lines 1-2: Delete name of U.S. company, description of item, and name of Chinese end-user.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 28.  
See comment 15.

Page 24, line 3: Delete name of Chinese end-user.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 28.  
See comment 15.

Page 24, lines 5-8: Delete name of U.S. company, description of item and Chinese end-user.

*Rationale:* Disclosure of such application-specific information is precluded under section 12(c) of the Export Administration Act of 1979, as amended.

Now on p. 28.  
See comment 16.

Page 24: This conclusion is based on an inaccurate understanding of U.S. export control policy.

Now on pp. 29 and 30.  
See comment 16.

Page 25: These recommendations are based on an inaccurate understanding of U.S. export control policy.


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The following are GAO's comments on the letter from the Department of Commerce dated January 16, 2002.

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## GAO Comments

1. We have modified the text on pages 23 and 24 to better distinguish between the policy articulated in the Export Administration Regulations and agency practice. We agree that the regulations discuss U.S. policy toward the export of goods and technology to China and do not include a discussion of the "two-generations-behind" objective. However, in March 2001, senior executive branch officials involved in making U.S. policy, including the undersecretary of commerce for export administration and the director of the Technology and Security Directorate of the Defense Threat Reduction Agency, stated that the U.S. government's practice, while undocumented, aims at keeping China's manufacturing capability two generations behind commercial state of the art. This view was confirmed by the chairman of the Information Services Technical Advisory Committee—an industry advisory committee. Further, the Commerce Department said in its detailed written comments on this report that the "two-generations-behind" practice has been used in making some export licensing decisions.
2. In discussions with U.S. government officials, we found a lack of understanding and information about the semiconductor manufacturing equipment and materials industry. For example, Foreign Commercial Service officials in Shanghai, the center of China's semiconductor manufacturing industry, welcomed our visit as an opportunity to learn more about the industry and meet with industry representatives and said they had been unable to complete a study of China's semiconductor industry due to a lack of resources.
3. We have modified the text of the report on page 25 to note that neither the semiconductor equipment producers nor industry associations have requested a foreign availability study. However, we further note in the revised report that industry representatives had not requested a study because the government's prior efforts to conduct a study took several years to complete and were outdated at issuance. Industry officials told us that if new studies were conducted and completed in a timely manner the results would indicate that U.S. export controls on the items studied have been ineffective, since all the equipment necessary to manufacture semiconductors can be purchased from non-U.S. sources.

4. 
5. We met with agency officials and explained that all of the company-specific information cited in the report was gleaned from public sources or was provided to GAO by the companies mentioned.
6. We have revised the highlights page to include discussion of the policy as set forth in 15 C.F.R., section 742.4, and the U.S. government's two-generations-behind practice.
7. Page 24 now discuss the policy as set forth in 742.4 and the U.S. government's two-generations-behind practice. See also comment 1.
8. "of 1979" has been inserted on page 6 after "Export Administration Act."
9. No change made. The level of detail contained in the report is sufficient.
10. No change made. The objective of the Wassenaar Arrangement is fully described in the report.
11. No change made. The line cited is from the introductory paragraph. Additional more detailed information follows.
12. See comment 5.
13. Change made. Additional text added has been added on page 23 of the report.
14. Additional information has been added to page 24 of the report to reflect the stated U.S. government policy and the differences between the policy and the U.S. government's practice.
15. See comment 5.

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16. Additional information has been added to page 24 of the report to reflect the stated U.S. government policy and the difference between the policy and the U.S. government's practice.

# Comments from the Department of Defense

Note: GAO comments supplementing those in the report text appear at the end of this appendix.



POLICY

OFFICE OF THE UNDER SECRETARY OF DEFENSE  
2000 DEFENSE PENTAGON  
WASHINGTON, DC 20301-2000

17 JAN 2002

Mr. Joseph Christoff  
Director, International Affairs and Trade  
United States General Accounting Office  
Washington, DC 20548

Dear Mr. Christoff:

This letter and detailed comments, attached, constitute the Defense Technology Security Administration's (DTSA) response to the General Accounting Office's (GAO) draft report entitled, "EXPORT CONTROLS: Rapid Advances in China's Semiconductor Industry Underscore the Need for Fundamental U.S. Policy Review," dated December 19, 2001 (GAO Code 320025/ GAO-02-151). The Defense Technology Security Administration is the central point of contact for development and implementation of export control policies and related matters for the Department of Defense.

I appreciate the opportunity to comment on the draft report, as well as the level of effort that clearly has gone into the current product. Moreover, I would welcome an opportunity for our staffs to work together in greater detail as you finalize this report. While I believe the report correctly identifies a number of policy challenges relating to semiconductors and China, we have extensive concerns about the accuracy of the current draft as well as more fundamental concerns about the draft's final recommendations. In particular, the U.S. does not have a policy of "trying to keep Chinese industry at least two generations behind the U.S." U.S. policy is contained in the Export Administration Regulations (EAR). Semiconductor manufacturing related items are controlled to China for national security reasons.

The attached detailed comments, provide a range of factual corrections and recommendations for changed emphasis in order to produce a more accurate final product. I appreciate GAO's efforts in this important area. My staff stands ready to assist you during the revision of the draft report.

Lisa Bronson  
DUSD, Technology Security Policy and  
Counterproliferation

Enclosure:  
As stated





**DEFENSE TECHNOLOGY SECURITY ADMINISTRATION  
DETAILED COMMENTS ON**

**GAO DRAFT REPORT DATED DECEMBER 19, 2000  
(GAO CODE 320025) GAO-02-151**

**“EXPORT CONTROLS: Rapid Advances in China’s Semiconductor  
Industry Underscore the Need for Fundamental U.S. Policy Review”**

**DTSA DETAILED COMMENTS:**

See comment 1.

Title page: “Rapid Advances in China’s Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review.” Recommend that the title should be revised to read: “Advances in China’s Semiconductor Industry Underscore Need for Continued Review of U.S. Policy.”

See comments 2 and 3.

Highlights page, first paragraph (under “What the GAO Found”), line 2 and 3: “rapidly narrowed”, “less than one generation behind” should be revised.

Rationale: In fact, China is still closer to two generations behind. See discussion, below, about the feature size plot and the state of production at various facilities in China. If the current trends, as represented in the feature size plot, continue, China’s commercial semiconductor manufacturing industry will match the state-of-the-art by 2008, consistent with the RAND report, “The Military Potential of China’s Commercial Technology” (Report Number, MR-1292-AF, ISBN 0-8330-2939-8, 2001, and available online at [www.rand.org](http://www.rand.org)). In addition, there is no U.S. policy to stay two generations ahead of China in semiconductor production. U.S. export control policies in this and other areas are codified in various sections of the Export Administration Regulations.

See comments 4 and 5.

Highlights page, first paragraph, line 4-7: “The growing sophistication of China’s semiconductor manufacturing facilities...has improved its ability to develop more capable weapons systems” should be deleted.

Rationale: There is no evidence that these companies - many of which have not sold any products yet - have produced any controlled electronics for use by the Chinese military. Although GAO visited semiconductor production facilities in China, the report does not provide details on which products are being produced and for which applications. Licensed semiconductor manufacturing equipment exports to China from the U.S. are limited to the production of uncontrolled

products by virtue of conditions included in the export license. No evidence of Chinese end-user's failure to conform to license conditions has been presented.

Highlights page, third paragraph: Should be substantially revised.

Rationale: There is no formal U.S. policy to "keep China...two generations behind." U.S. policy governing export controls is based on DoD Directive 2040.2 and the Export Administration Regulations (EAR). "Generation" issues relate exclusively to very large scale integration (VLSI) digital complimentary metal oxide semiconductor (CMOS) technology associated with silicon-based microcircuits. The report cites cases involving compound semiconductor manufacturing equipment. These cases do not have a "generation issue."

The statement "This objective has not been documented." should be deleted, because the objective does not exist.

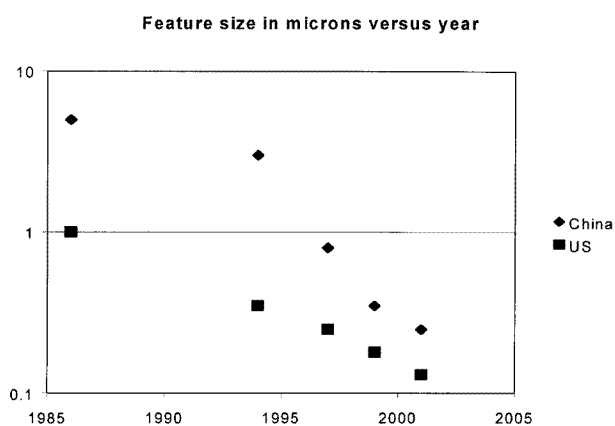
The statement "[T]he executive branch does not have a sound, analytical basis for approving or denying export licenses for this technology" should be deleted. The report omits references to policy documents that govern DoD's review of semiconductor manufacturing exports to China. These documents include 1) DoD Directive 2040.2, which, among other things, mandates case-by-case review with regard to potential impact of an export on national security, and 2) the Export Administration Regulation Section 742.4(b)7, which recommends extended review or denial for proposed exports that "make a direct and significant contribution to electronic and anti-submarine warfare, intelligence gathering, power projection, and air superiority." These mission areas are of particular concern in reviews of semiconductor manufacturing export license applications for China.

The statement that the U.S. requires licenses "without adequately consideration of global market forces" is incorrect. DTSA personnel participate in periodic meetings with industry advisory committees. We are aware of foreign sources and global market forces. U.S. officials often engage in discussions with foreign governments over concerns regarding active export cases.

Highlights page: Plot of feature size versus year (which also occurs again later in report body) should be revised.

Rationale: The plot shown should have a semi-log axis for "feature size" since the pace of improvement is geometric (footnote 4, page 4). The time scale should be linear. SMIC was only at 0.25 microns (see press release dated November 22, 2001, at [www.smics.com/newimg/press1122.htm](http://www.smics.com/newimg/press1122.htm)) in 2001. Assuming the 2001 China data point is based on Table 1, page 11, of the draft report, then the data

point for China in Figure 1 should be corrected from 0.18 to 0.25 microns. Figure 1 would then appear as follows:



This graph gives a clearer picture of the rate of advancement of China relative to the U.S. and also shows that China is still closer to two generations behind the U.S. as opposed to one generation as stated in the report.

A general concern is that the draft report never defines “semiconductor manufacturing equipment” subject to export controls when the destination is China. For information, the following table summarizes the semiconductor equipment (3B) and materials (3C) subject to export controls to China. Also included is a brief description of the national security concern.

See comment 11.

**Appendix IV**  
**Comments from the Department of Defense**

Description of Semiconductor Production Equipment and Materials Requiring Export Licenses to China

CCL <sup>1</sup> Paragraph	Brief Description	National Security Significance	Primary Supplier Countries	Control Reason	Exceptions
3B001.a.1	Thin layer deposition equipment	Radiation-hardened electronics, space-qualified solar cells, high power radio-frequency devices, infrared focal plane arrays	US, Japan	NS <sup>2</sup>	CIV <sup>3</sup>
3B001.a.2	MOCVD <sup>4</sup> reactors		US, Germany	NS	None
3B001.a.3	MBE <sup>5</sup> equipment		US, UK	NS	None
3B001.b	Ion implantation equipment	Used for radiation hardened circuitry	US, Japan	NS	None
3B001.c	Plasma dry etching equipment	Needed for all state-of-the-art electronics, commercial or military. Enable production of controlled analog-to-digital (ADC) converters, field programmable logic devices (FPLD), and application specific integrated circuits (ASICs). These items are controlled under the Export Administration Regulations (EAR) in 3A001 and 3A101 or under the International Traffic in Arms Regulations (ITAR) Category XI.	US, Japan	NS	None
3B001.d	Plasma enhanced CVD		US, Japan	NS	None
3B001.e	Cluster tools		US, Japan	NS	None
3B001.f.1	Lithography systems	These items are controlled under the Export Administration Regulations (EAR) in 3A001 and 3A101 or under the International Traffic in Arms Regulations (ITAR) Category XI.	US, Netherlands, Japan	NS	None
3B001.f.2	Mask lithography systems		US, Japan, Sweden	NS	None
3B001.g	Masks		US, Japan	NS	None
3B001.h	Multi-layer masks	Potential starting material for devices outlined in MOCVD and MBE block	US, Japan	NS	None
3B002.a	S-parameter testers		US, Japan	NS	None
3B002.b	Integrated circuit testers		US, Japan, Germany	NS	None
3C001.a	Epitaxial Silicon Wafers	Same as for 3B001.c	US, Japan, European Countries, Taiwan	NS	None
3C001.b	Epitaxial Germanium Wafers			NS	None
3C001.c	Epitaxial wafers of III/IV Compounds			NS	None
3C002	Photo resists	Gas sources for MOCVD	US, Japan, Europe	NS	None
3C003	Purified metal organics			NS	None
3C004	Purified gases			NS	None

1 CCL = Commerce Control List

2 NS = National Security

3 CIV = a civilian end use license exception. Only exports to military end users require export licenses.

4 MOCVD = Metal Organic Chemical Vapor Deposition

5 MBE = Molecular Beam Epitaxy

Now on pp. 2 and 3.  
See comment 12.

Page 2, line 30-32: “[T]he United States is the only member of this voluntary arrangement that considers China’s acquisition of semiconductor manufacturing equipment a cause for concern.” Should be revised.

Rationale: Bilateral discussions are held with other countries that manufacture this equipment. These countries are always willing to discuss concerns. Only at most five countries, and primarily just two (the U.S. and Japan), produce the bulk of semiconductor manufacturing equipment.

See comment 13.

Page 3, line 1: “[F]ewer items have been subject to Wassenaar’s controls.” Should be revised.

Rationale: This statement is misleading as it references the overall Wassenaar control list. The following table summarizes changes in controls for semiconductor manufacturing equipment and materials (3B and 3C, the entire focus of this report) from 1997 to present (2001 changes have not been finalized by Wassenaar).

Changes to the Wassenaar List in Categories 3B and 3C

Year	Item	Brief Description	Characterization
2000 <sup>1</sup>	3.B.1.c.	Introduced control for plasma dry etch etching equipment	New Control
	3.B.1.d	Introduced control for plasma enhanced CVD equipment	New Control
	3.B.2.b	Modified application note to clarify that testers for memories are not controlled	Clarification
	3.C.1	Added control for silicon carbide wafers	New Control
1999 <sup>2</sup>	3.B.2.b	Liberalized pattern rate control for integrated circuit testers (60 to 333 MHz)	Liberalization
	3.B.2.d	Removed [obsolete] control for electron beam and laser beam systems	Decontrol
1998 <sup>3</sup>	3.B.1.a.3	Added control for Molecular Beam Epitaxial (MBE) growth equipment	New Control
	3.B.1.b.1&2	Liberalized controls for ion implanters	Liberalization
	3.B.1.f	Clarified lithography equipment controls to include direct step and step and scan equipment	Clarification
	3.B.1.f	Relaxed controls on lithography equipment wavelength and minimum resolvable feature size	Liberalization
	3.C.2.a	Relaxed wavelength controls on positive resists	Liberalization
1997 <sup>4</sup>	3.B.2.b	Liberalized pattern rate control for integrated circuit testers (50 to 60 MHz)	Liberalization

<sup>1</sup> Summary of the changes made to the List of Dual-Use Goods & Technologies and the Munitions List as of 01 December 2000, Wassenaar Arrangement web site, [www.wassenaar.org](http://www.wassenaar.org).

<sup>2</sup> Federal Register, 65 FR 43130, 12 July 2000

<sup>3</sup> Federal Register, 64 FR 40106, 23 July 1999

<sup>4</sup> Federal Register, 63 FR 2452-2555, 15 January 1998

Since individual items can have significantly different impacts on national security, tallying these proposals as the report does in its Figure 5, page 20 is not recommended.

See comment 14.

Page 3, line 14-15: “[T]he executive branch does not have a sound, analytical basis for approving or denying export licenses”. Should be revised.

Rationale: See DoD Directive 2040.2 and EAR 742.4(b)7.

Now on p. 7.  
See comment 15

Page 5, line 17-19: “Category 3 goods and technologies are controlled primarily as a tool of U.S. anti-terrorism policy.” Should be revised.

Rationale: The primary control concern regarding China is national security, not anti-terrorism, as expressed in the EAR (it should be noted that the Wassenaar Arrangement has added “terrorism” to “security” as a reason for control at its December 2001 Plenary).

Now on p. 8.  
See comment 16.

Page 6, line 15-16: “Transparency, through exchanging information and sharing, is the sole means by which the arrangement tries to achieve its goals.” Should be revised.

Rationale: Transparency, while important, is but one method used by the Wassenaar Arrangement to achieve its goals. The Basic List is reviewed annually to ensure that it contains items and technology of concern that should require special scrutiny, i.e., a license, when being exported. Similarly, the Sensitive List and the Very Sensitive List are also reviewed. From a policy perspective, the U.S. has supported Wassenaar Arrangement members adopting “catch all, catch more” controls that enable countries to prohibit the export of uncontrolled items of concern when destined to end-users of concern. The U.S. delegation also took the lead this past year in ensuring that “terrorism” was added to the considerations of the Wassenaar Arrangement.

See comment 17.  
Now on p. 9.

Page 7, title in margin: Should be revised.

Rationale: The Chinese “Defense Industrial Base” is mentioned as having improved. However, the draft report gives no evidence to support the conclusion that Chinese military capabilities have been improved through advances in semiconductor manufacturing.

Now on p. 9.  
Now footnote 18.  
See comment 18.

Page 8: Footnote 16: is awkwardly worded and should be revised.

Rationale: The intent is to indicate that extending the feature size capability of a particular generation of semiconductor manufacturing equipment beyond its designed operating range can produce transistors with smaller feature size and higher performance, but results in lower yield of functional die (circuits) per wafer and does not significantly increase the number of transistors per unit area. To do the latter requires transitioning to the next generation of lithography equipment.

Page 8: Footnote 17. Recommend that specific references or sources be identified for the statements in this footnote.

Page 9: The plot of feature size versus year should be revised as discussed above in the "Highlights" page comments.

Page 11: Table 1. Should be substantially revised.

Rationale: As noted above, SMIC is not producing at 0.18 micron. In 2001, SMIC, Grace, and Motorola had no production of note from their Chinese semiconductor manufacturing facilities. The table should be revised to differentiate companies that are presently manufacturing versus companies in a planning stage.

Page 12, line 6: "[I]n an effort to improve the semiconductor manufacturing equipment constructed in China". "Equipment" should be changed to "facilities."

Rationale: China does not construct semiconductor manufacturing equipment meeting the Wassenaar Arrangement control specifications.

Page 12: Footnote 18. Should be revised or clarified.

Rationale: Applied Materials has a comprehensive line of equipment. Most of these items are not subject to U.S. export controls. It is not clear in the draft whether 2% is the figure associated with equipment requiring an export license, or associated with total sales to China.

Page 13, line 12-13: "[P]rovide China's military with a new source of custom made integrated circuits." Should be deleted.

Rationale: As noted above, the draft report cites no evidence of controlled integrated circuits produced for civilian or military applications. Also as noted above, facilities receiving semiconductor manufacturing equipment or materials

Page 7 of 12

Now on p. 10.  
Footnote 19.  
See comment 19.

Now on p. 10.  
See comments 20 and 21.

See comments 20 and 21.

Now on p. 13.  
See comment 22.

Now on p. 13.  
Now footnote 20.  
See comment 23.

Now on p. 15.  
See comment 24.

under U.S. export license are subject to license conditions restricting production to uncontrolled products only.

Page 14, line 12-13: "China's defense industry faces technical, structural, and cultural barriers that impede its ability to absorb and utilize advanced technologies for weapons production." Should be deleted.

Rationale: This assertion is subjective at best, particularly with respect to "cultural barriers."

Page 15, line 9-10: "Transparency ... is the sole means by which the arrangement tries to achieve its goals." Should be revised.

Rationale: See comment above relating to transparency.

Pages 15, line 12 & Page 16, line 10: "97 percent of all electronics-related items" should be revised.

Rationale: If a percentage must be used, it should be a percentage of all semiconductor manufacturing equipment and materials (Category 3B and 3C) and not of all electronics (Category 3).



Page 16: Footnote 27. "4 out of 127" should be X out of XX where X and XX are the number of controlled items and total items in 3B and 3C respectively.

Rationale: The focus of the report is semiconductor manufacturing equipment and materials.

Pages 17 and 18: With respect to analysis of individual license applications, confidentiality provisions in the EAA prevent public disclosure of such information.



Now on p. 23.  
Now footnote 41.  
See comments 31 and 32.

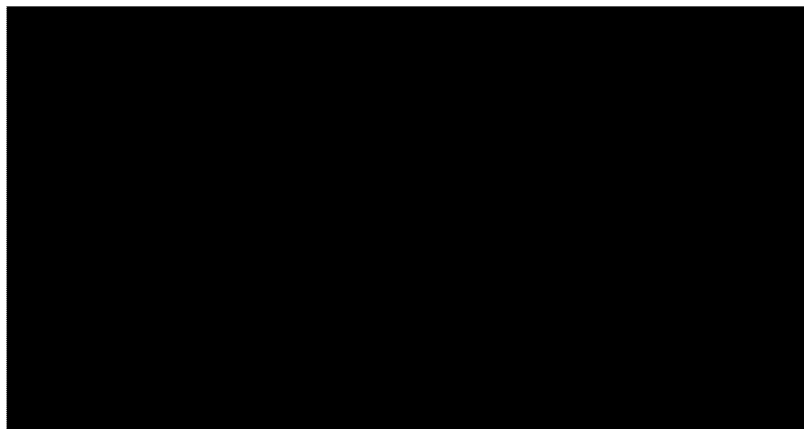
Now on p. 23.  
See comments 31 and 32.

Now on p. 23.  
See comments 33 and 34.

Now on pp. 23 and 24.  
See comments 33 and 34.

Now on p. 26.  
See comment 35.

Now on p. 27.  
See comment 36.



Page 21, line 5-6: "United States' policy objective is to keep China at least two generations (about 3 to 4 years) behind". Should be deleted.

Rationale: As previously discussed, this is not a U.S. policy.

Page 21, line 30-32: "[The government] has not defined what 'two generations' or 'commercial state-of-the-art production' ... means." Should be deleted.

Rationale: There is no "two generation" policy, and therefore it is not defined in export control regulations or other official documents.

Page 23, line 5: "[T]he Defense Department has not substantively updated the Military Critical Technologies List pertaining to semiconductor equipment and materials since 1996." Should be revised.

Rationale: The MCTL is published on the internet at <http://www.dtic.mil/mctl/>. The electronics section (Section 5) was last reviewed and updated in March 1999.

Page 23, line 11-14: "70.6 percent of export licenses for semiconductor manufacturing equipment (Category 3B) were approved and 83.3 percent of export licenses for semiconductor manufacturing materials (Category 3C) were approved." Should be revised and clarified.

Rationale: It is unclear whether these figures apply only to exports to China, or to all destinations during those years. This statement also fails to consider restrictive

Now on p. 28.  
See comment 37.

conditions that could have been applied to the licenses to protect U.S. national security interests.

Page 24, line 7-9: "Due to delays in the license approval process, the firm canceled its ETEC order." Should be deleted.

Rationale: Due to confidentiality provisions in the EAA, public disclosure of information regarding individual license applications is not authorized.

Now on p. 28.  
See comment 38.

Page 24, line 11-13: "The current export control system has not effectively slowed China's ability to obtain billions of dollars worth of advanced semiconductor equipment." Should be revised to include a discussion of the Chinese military.

Rationale: The report provides no evidence of the Chinese military's access to controlled electronic components resulting from exports of controlled semiconductor manufacturing equipment to China.

Now on p. 29.  
See comment 39.

Page 24, line 26-28: "[W]ith no clear justification for why the current control parameters are maintained." Should be revised.

Rationale: The rationale and mechanisms for maintaining control parameters are outlined above.

Now on pp. 29 and 30.  
See comment 40.

Page 24 and 25: "Recommendations for Executive Action." Recommend recommendations be redrafted as follows:

Preamble: "In order to improve the effectiveness of the U.S. export control system, we recommend that the Secretary of Commerce *continue* to work with the Secretary of Defense and the Secretary of State to reevaluate, clarify, and document export policy on semiconductor manufacturing equipment and materials. These actions should include:

1. continued assessments of (a) foreign availability and (b) the technical requirements for protection of critical U.S. military capabilities, (c) the impact of export controls on U.S. industry, and (d) the overall national and economic security implications of China's ability to import, produce, and develop advanced semiconductor-related technology;
2. continued development of new export controls if a technology requires such control and in fact can be controlled. If the technology cannot be controlled using export controls, continue exploring alternative means for protecting U.S. security interests;

Page 10 of 12

3. continued review of the Wassenaar Arrangement and related regimes with an eye toward developing additional proposals to strengthen multilateral export controls; and

4. continued attention to communication with Congress and industry on technology security matters, including the results of any assessments undertaken, or options developed, pursuant to these recommendations.

Rationale: Regarding “documenting export policy,” We evaluate semiconductor equipment sales to China under the guidelines of Export Administration Regulations (EAR) 742.4(b)7, which recommends extended review or denial for exports that “make a direct and significant contribution to electronic and anti-submarine warfare, intelligence gathering, power projection, and air superiority.” These mission areas rely on electronic components that are export-controlled. The focus of semiconductor production equipment export controls, with respect to China in particular, is to prevent the transfer of equipment which would enhance China’s capability in the mission areas identified above.

Regarding “foreign availability,” the Department of Commerce is already directed to assess foreign availability, in consultation with the Secretary of Defense, under Export Administration Act (EAA) Section 5(f)(1), “Foreign Availability in Controlled Countries.” In practice, DTSA continuously evaluates foreign availability and capability through a number of means. For example, the draft report mentions cases involving metal-organic chemical vapor deposition (MOCVD) systems. We routinely sends engineers to conferences where producers of such systems demonstrate new developments and exchange technical information, a common means of keeping abreast of new developments in technical fields. In addition, the normal review of cases provides opportunities to maintain knowledge of foreign availability in specific product areas.

Regarding “technical parameters,” the technical parameters considered critical to the U.S. military are already reviewed periodically through the Military Critical Technologies List (MCTL), which is published on the Internet at <http://www.dtic.mil/mctl/>. The electronics section (Section 5) was last updated in March 1999. Sections 5.2 and 5.3 discuss electronic materials and production equipment, respectively. The List contains foreign capability determinations, though the document does not restrict itself solely to export-controlled items.

Regarding “national and economic security implications of China’s ability to import, produce and develop advanced semiconductor-related technology,” this is an area where discussion is ongoing and additional impact studies may be useful. The RAND Corporation recently published a report entitled “The Military Potential of China’s Commercial Technology” (Report Number, MR-1292-AF,

ISBN 0-8330-2939-8, 2001, available online at [www.rand.org](http://www.rand.org)). Section 3 discusses China's commercial microelectronics industry. This report concludes that China is 6-8 years behind the state-of-the-art at present and may catch up in approximately 2008. Some articles from the trade press indicate that China may become a major producer of some state-of-the-art semiconductor devices. See, for example, "Floodgates Open to China's Chip Industry", Solid State Technology, February 2001.

Regarding "developing new export controls," DTSA already develops proposals for, and participates in, interagency and Wassenaar list reviews. For example, in calendar 2000, we obtained new controls on plasma etch and chemical vapor deposition equipment. We regularly identify new technologies for possible control and continues to introduce new proposals for interagency consideration. In this regard, a DTSA-generated proposal to control spin on low-k dielectrics is currently under review. DoD is also researching other possible control proposals such as chemical mechanical planarization (CMP) equipment, which is critical for copper interconnects in integrated circuits.

Regarding "alternative means for protecting U.S. security interests," we have already supported bilateral meetings with governments of key technology-producing countries on alternative mechanisms to control critical items. For example, the Department is actively pursuing an anti-tamper program to reduce the risk of technology transfers detrimental to national security.

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The following are GAO's comments on the letter from the Department of Defense dated January 17, 2002.

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## GAO Comments

1. No change. The analysis and conclusions presented in our report support the need for a fundamental review of U.S. policy related to semiconductor equipment and materials exports to China.
2. The data presented in the report on the current state of China's semiconductor manufacturing capability are based on information we collected during our visits to Chinese semiconductor manufacturing facilities in 2001. The data demonstrate that China's most advanced manufacturing facilities currently contain equipment capable of producing semiconductors that are only one generation or less behind the current commercial state of the art. The author of the RAND Corporation study confirmed that his analysis was based on secondary information that is at least 3 years old.
3. We have modified the text on page 24 to better distinguish between the policy articulated in the Export Administration Regulations and agency practice. We agree that the regulations discuss U.S. policy toward the export of goods and technology to China and do not include a discussion of the "two-generations-behind" objective. However, in March 2001, senior executive branch officials involved in making U.S. policy, including the undersecretary of commerce for export administration and the director of the Technology and Security Directorate of the Defense Threat Reduction Agency, stated that the U.S. government's practice, while undocumented, aims at keeping China's manufacturing capability two generations behind commercial state of the art. The chairman of the Information Services Technical Advisory Committee--an industry advisory committee--also shared this view with us. Further, the Department of Commerce stated in its detailed written comments on this report that the "two-generations-behind" policy has been applied in making some export licensing decisions.
4. Additional information has been added on pages 15 and 16 to clarify the relationship between China's semiconductor manufacturing facilities and its military capabilities. However, we further note in the revised report that in testimony delivered to the U.S.-China Commission on January 17, 2002, the deputy undersecretary of defense technology security policy and counterproliferation stated that a "cutting-edge"


domestic semiconductor industry supports military modernization in China. This official testified that “China's military modernization program appears to be focusing on ‘pockets of excellence,’ where advances in select technologies can be leveraged for disproportionate benefit in a potential conflict. Several such ‘pockets’ include: preemptive long-range precision strike capabilities; information dominance; command and control; and integrated air defense. In support of these efforts, Beijing has identified the development of an indigenous microelectronics industry as one of its highest priorities. China's increasing emphasis on the development of integrated circuits will have direct application in future military systems, for example, advanced phased-array radar.”

5. We modified the report by adding more information on pages 27 and 28 about the conditions typically imposed on approved export licenses. Although these conditions are designed to deter the end user from using the U.S. equipment inappropriately, these conditions should be monitored on a regular basis. As noted in our report, the government lacks information on whether these conditions are being met. U.S. officials in China told us that they had not conducted any end-use checks on semiconductor manufacturing equipment in the last 5 years. Moreover, in testimony before the U.S.-China Commission on January 17, 2002, the Commerce Department's assistant secretary of export enforcement noted some problems with these checks and said the schedule for conducting end-use checks is dictated by the Chinese government. The official testified that most of the end-use checks that the United States has been allowed to conduct in China have been on high-performance computers that are no longer controlled because of the liberalization of U.S. export controls. In addition, this official noted that due to delays caused by the Chinese government's scheduling, 700 outstanding checks remain to be completed and checks on items other than high-performance computers continue to “languish.”
6. See comment 3.
7. See comment 3.
8. See comment 3 and comment 14.
9. In discussions with U.S. government officials, we found a lack of understanding and information about the semiconductor manufacturing equipment and materials industry. For example,

Foreign Commercial Service officials in Shanghai, the center of China's semiconductor manufacturing industry, welcomed our visit as an opportunity to learn more about the industry and meet with industry representatives and said they had been unable to complete a study of China's semiconductor industry due to a lack of resources.

10. We modified figure 1 to give a clearer picture of China's rate of advancement relative to the United States. However, the data points used in the chart have not been changed as they are based on primary data sources including the president of the Semiconductor Manufacturing International Corporation.
11. We have added information from this table to appendix I, page 39, to clarify the types of items the report discusses. The report generally refers to controlled semiconductor manufacturing equipment and materials (all of Categories 3B and 3C).
12. We agree that countries are willing to listen to U.S. concerns pertaining to the export of semiconductor manufacturing equipment and materials to China. The United States is the only member that considers the relationship between semiconductor manufacturing equipment and military end uses sufficiently critical and considers China's acquisition of this technology a potential threat to regional or international stability.
13. Additional text has been added to page 23 that includes the Defense Department information pertaining to proposals in Category 3B and Category 3C. Although the Defense Department's chart shows that four new controls were added, it also shows that one item was decontrolled and that controls on five additional items were relaxed.
14. We modified our report on page 24 by adding language from Export Administration Regulation 742.4(b)(7). This regulation provides a general statement of U.S. export policy for China. However, as noted in our report, it does not specify the level of semiconductor manufacturing technology that can be exported to China relative to the current state of the art. Although Department of Defense Directive 2040.2 establishes policy, assigns responsibility, and prescribes procedures for international transfer of defense-related technology, goods, services, and munitions, it has not been updated since July 5, 1985, and a number of its provisions are centered on the now defunct

Coordinating Committee for Multilateral Export Controls (COCOM), the predecessor to the Wassenaar Arrangement.

15. We modified page 7 of the report to clarify why this technology is controlled.
16. No change. The updating of control lists and other efforts to improve these lists are all aspects of transparency. Adding or deleting items from the lists simply alters the reporting requirements for those items.
17. See comment 4.
18. Footnote 18 has been reworded to clarify the information presented.
19. Footnote 19 has been reworded to clarify the information presented.
20. See comment 10.
21. See comment 10.
22. No change. The statement made in the report refers to China's efforts to develop an indigenous semiconductor manufacturing equipment industry, not to efforts to improve its facilities.
23. No change. The 2 percent refers to the total sales to China.
24. See comments 4 and 5.
25. The text on pages 16 and 17 has been modified to clarify the characterization of the problems facing China's defense industry. The information presented was obtained from papers published by defense experts, GAO interviews with defense experts, and the RAND Corporation study cited in the Defense Department comments on a draft of this report.
26. See comment 16.
27. Additional information pertaining to Categories 3B and 3C was added to footnote 30.
28. 



- [REDACTED]
29. Additional information was added to footnote 30 pertaining to Categories 3B and 3C.
30. The information presented in the report pertaining to specific companies was obtained from the companies or from public sources.
31. [REDACTED]
32. [REDACTED]
33. See comment 3.
34. See comment 3.
35. The Internet site does indicate that some revisions were made to the electronics section in 1999. However, the analyst responsible for the list stated that the list had not been substantively updated since 1996.
36. Information was added to page 27 of the report to indicate that the information presented pertains to China.
37. The information presented in the report pertaining to specific companies was obtained from the companies or public sources.
38. See comments 4 and 5.
39. See comment 3.
40. The report clearly illustrates the contrast between formal U.S. export control policy articulated in the Export Administration Regulations and practice. It also reveals the lack of an analytical basis for export control licensing decisions and proposals for the Wassenaar Arrangement. The report also highlights the continuing ineffectiveness of the Wassenaar Arrangement as a means for controlling the export of semiconductor manufacturing equipment and materials to China. Meanwhile, China's defense industrial base continues to obtain benefits from the modernization of China's semiconductor manufacturing

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industry that is driven by the acquisition of advanced semiconductor manufacturing equipment and materials from foreign sources, including the United States. A fundamental reevaluation of U.S. policy on export controls on semiconductor manufacturing equipment and materials to China is, therefore, necessary to correct weaknesses in the current system.

# Comments from the Department of State

Note: GAO comments supplementing those in the report text appear at the end of this appendix.



United States Department of State  
Chief Financial Officer  
Washington, D.C. 20520-7427

January 9, 2002


Dear Ms. Westin:

We appreciate the opportunity to review your draft report, "EXPORT CONTROLS: Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review," GAO-02-151, GAO Job Code 320025.

The Department's comments are enclosed for incorporation, along with this letter, as an appendix to the GAO final report. Please find technical comments also enclosed.

If you have any questions regarding this response, please contact [REDACTED] Office of Export Controls and Conventional Arms Nonproliferation Policy, Bureau of Nonproliferation [REDACTED]

Sincerely,

  
Larry J. Eisenhart  
Acting

Enclosures:

As stated.

cc: GAO/IAT - Mr. Christoff  
State/OIG - Mr. Atkins  
[REDACTED]

Ms. Susan S. Westin,  
Managing Director,  
International Affairs and Trade,  
U.S. General Accounting Office,  
Washington, DC 20548.

Department of State Comments on Draft Report

**EXPORT CONTROLS: Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review**  
(GAO-02-151, GAO Code 320025)

The Department of State is pleased to have the opportunity to comment on the draft report. Although the draft report includes much useful information on China's development of semiconductor manufacturing, we disagree substantially with its policy analysis and conclusions.

See comment 1.

A critical reason for this is because the draft report is based on a flawed premise: that U.S. export controls on semiconductor manufacturing-related items to China are supposedly based on a flawed policy of trying to keep Chinese industry at least two generations behind the U.S. Continuing on with this flawed premise, the draft report criticizes the lack of analysis, clarity, and documentation surrounding the alleged "two generations behind" policy.

See comments 1 and 2.

In fact, however, the supposed "two generations behind" policy for exports to China of semiconductor manufacturing-related items is not U.S. government policy. That this is not U.S. policy is apparent not only from the absence of documentation concerning such a policy (as noted in the draft report), but from U.S. export licensing decisions themselves -- including some decisions mentioned in the draft report (e.g., the Motorola export noted in Table 1 on page 11).

See comment 3.

Instead, U.S. policy for why these items should be controlled and how exports should be reviewed is clearly and formally articulated in the Export Administration Regulations -- a fact completely overlooked in the draft report. According to the EAR, semiconductor manufacturing-related items are controlled to China for National Security reasons.

-- Section 742.4(a) notes that National Security items such as semiconductor manufacturing-related items are controlled because "It is the policy of the United States to restrict the export and reexport of items that would make a significant contribution to the military potential of any other country or combination

of countries that would prove detrimental to the national security of the United States."

- The licensing policy for National Security items such as semiconductor manufacturing-related items is noted in Section 742.4(b) of the EAR, including the China-specific Section 742.4(b)(7), which notes "the general licensing policy is to approve applications, except that those items that would make a direct and significant contribution to electronic and anti-submarine warfare, intelligence gathering, power projection, and air superiority receive extended review or denial. Each application will be considered individually. Items may be approved even though they may contribute to Chinese military development or the end-user or end-use is military."

It is clear from the EAR itself, therefore, that the U.S. has clear, documented reasons for control and licensing policies for semiconductor manufacturing-related items -- and policies substantially different from those attributed to the government in the draft report.

U.S. controls on exports to China of semiconductor manufacturing-related items have, in fact, supported the stated policy objective of "restrict[ing]...items that would make a significant contribution to the military potential...that would prove detrimental to the national security." Indeed, the draft report does not identify any licensed U.S. exports of such items to China that made such a "significant contribution." This is due in substantial part to the government's thorough reviews of applications to export semiconductor manufacturing in China, and the extensive license conditions imposed to minimize national security concerns -- something also overlooked in the draft report, which implicitly assumes that any exported items are freely available to China for unlimited military use. In our view, the draft report does not provide a national security rationale for its recommendation that new U.S. export controls or alternatives to export controls are needed.

Furthermore, contrary to implications in the draft report, the U.S. export licensing process does in fact consider the nature and extent of foreign availability of manufacturing equipment as well as product (chips), and the cumulative effect of those exports to China of which we are

See comments 4 and 5.

See comment 6.

aware, as well as the potential risks to U.S. national security. Disturbingly, the draft report downplays the extent to which the U.S. dual-use export licensing community is informed -- largely by frequent, detailed industry briefings, but also by intergovernmental contacts, the international press, and information exchanges in the Wassenaar Arrangement -- of Chinese semiconductor manufacturing capabilities. The efforts already undertaken are, in our view, sufficient to meet the intent of the draft report's recommendation concerning assessments of foreign availability and other factors related to export control of semiconductor manufacturing-related items.

See comment 7.

As to the controls exercised collectively by the 33 countries of the Wassenaar Arrangement, the draft report has not identified any exports by the U.S. or other Wassenaar countries of semiconductor manufacturing-related items to China that were inconsistent with the purposes of the Arrangement -- i.e., that contributed to military capabilities that undermine regional and international security, or the prevention of destabilizing accumulations of conventional arms and dual-use goods and technologies. Even exports by Wassenaar countries contrary to the alleged "two generations behind" policy were not characterized by the draft report as being contrary to the purposes of the Arrangement.

See comment 8.

In its criticisms of the effect of the current export control system on China's acquisition of sophisticated semiconductor manufacturing equipment, the draft report does not consider the consequences of having no U.S. or Wassenaar export controls over such items. It is almost axiomatic that, without such controls, China would have more effectively obtained even more advanced semiconductor equipment, at an earlier date, with fewer restrictions on its use, than it has managed thus far. Certainly, unconstrained exports would have had a much greater negative effect on U.S. national security -- and, after all, it is the effect on national security rather than the numbers of licenses granted or chip plants built that is the reason behind the export controls.

See comment 9.

Finally, the draft report is replete with Wassenaar Arrangement information that the U.S. government is committed internationally to keep confidential (in particular, pages 15, 17, 19-20, 26, 31 and footnote 30). In its current form, the draft is classified SENSITIVE BUT

UNCLASSIFIED and therefore cannot be released publicly. We will be happy to look over the next version of the draft -- which we hope will take into account the above comments, as well as the attached set of more focused comments -- to replace or remove protected language if you wish for the final report to be unclassified.

The Department of State again notes its appreciation for being able to comment on the draft report, and remains prepared to work with GAO on this and related issues.

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The following are GAO's comments on the letter from the Department of State dated January 9, 2002.

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## GAO Comments

1. We have modified the text on page 24 to better distinguish between the policy articulated in the Export Administration Regulations and agency practice. We agree that the regulations discuss U.S. policy toward the export of goods and technology to China and do not include a discussion of the "two-generations-behind" objective. However, in March 2001, senior executive branch officials involved in making U.S. policy, including the undersecretary of commerce for export administration and the director of the Technology and Security Directorate of the Defense Threat Reduction Agency, stated that the U.S. government's practice, while undocumented, aims at keeping China's manufacturing capability two generations behind commercial state of the art. This view was confirmed by the chairman of the Information Services Technical Advisory Committee—an industry advisory committee. Further, the Department of Commerce said in its detailed written comments on this report that the "two-generations-behind" practice has been used in making some export licensing decisions.
2. During our visit to the Motorola facility in Tianjin, China, we found that the U.S. government approved export licenses allowing the sale of 0.25-micron equipment. The equipment in the Motorola facility is two generations behind commercial state of the art, which is 0.13 micron.
3. We modified the report to clarify existing export control policy for semiconductor manufacturing-related items on page 24. We also describe the reasons for controlling dual-use goods further in appendix I, page 36.
4. We agree that no single piece of semiconductor manufacturing equipment exported to China will make a "significant contribution" to China's military. Rather, it is the cumulative effect of these exports that raises national security concerns. According to defense experts, the newest semiconductor manufacturing facilities constructed in China represent a significant improvement to China's military industrial base. It is the cumulative effect of exports of semiconductor manufacturing equipment from the United States and other Wassenaar members that has allowed China to improve its military industrial base. This is a scenario that was overlooked in the State Department's comments.



5. We modified pages 27 and 28 by adding more information about the conditions typically imposed on approved export licenses. Although these conditions are designed to deter the end user from using the U.S. equipment inappropriately, these conditions should be monitored on a regular basis. As noted in our report, the government lacks information on whether these conditions are being met. U.S. officials in China told us that they had not conducted any end-use checks on semiconductor manufacturing equipment in the last 5 years. Moreover, in testimony before the U.S. China Commission on January 17, 2002, the Commerce Department's assistant secretary of export enforcement noted some problems with these checks and said the schedule for conducting end-use checks is dictated by the Chinese government. The official testified that most of the end-use checks that the United States has been allowed to conduct in China have been on high-performance computers that are no longer controlled because of the liberalization of U.S. export controls. In addition, this official noted that due to delays caused by the Chinese government's scheduling, 700 outstanding checks remain to be completed and checks on items other than high-performance computers continue to "languish."
6. In discussions with U.S. government officials, we found a lack of understanding and information about the semiconductor manufacturing equipment and materials industry. For example, Foreign Commercial Service officials in Shanghai, the center of China's semiconductor manufacturing industry, welcomed our visit as an opportunity to learn more about the industry and meet with industry representatives and said they had been unable to complete a study of China's semiconductor industry due to a lack of resources. Furthermore, the information sources mentioned by the State Department, such as information exchanges and international press articles, are not adequate substitutes for a formal, comprehensive study.
7. As our report notes, weaknesses in Wassenaar reporting make it difficult to assess whether any exports covered by the arrangement were "contrary to the purposes of the Arrangement." Also, since all export control decisions of Wassenaar members are based on the national discretion of member countries, judgments of whether particular exports are contrary to the purposes of the arrangement are matters subject to a member state's interpretation.

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8. The report discusses some of the overall weaknesses in U.S. export control policy and practice, of which the Wassenaar Arrangement is one part, and recommends that the executive branch consider new ways of controlling this technology, if appropriate. It is not appropriate to speculate on the consequences of not having U.S. export controls or the Wassenaar Arrangement.

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# GAO Contact and Staff Acknowledgments

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## GAO Contact

Stephen Lord (202) 512-4379

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## Acknowledgments

In addition to the individual named above, David M. Bruno, Janey Cohen, Julie Hirshen, Richard Seldin, Kevin Tarmann, and Hai Tran made key contributions to this report.

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